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# EFFECT OF HIGH-TEMPERATURE CREEP AND OXIDATION ON RESIDUAL ROOM-TEMPERATURE PROPERTIES FOR SEVERAL THIN-SHEET SUPERALLOYS

*by Dick M. Royster and W. Barry Lisagor*

*Langley Research Center*

*Hampton, Va. 23365*



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16. Abstract

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# EFFECT OF HIGH-TEMPERATURE CREEP AND OXIDATION ON RESIDUAL ROOM-TEMPERATURE PROPERTIES FOR SEVERAL THIN-SHEET SUPERALLOYS

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## SUMMARY

Superalloys are being considered for the primary heat shields and supports in the thermal protection system of both hypersonic-transport and space-shuttle vehicles. Since conservative design philosophy dictates designs based on residual material properties at the end of the service life, material characterization after exposure to the environmental conditions imposed by the flight requirements of these two classes of vehicles is needed on the candidate alloys. An investigation was conducted to provide some of the necessary data, with emphasis placed on oxidation, creep, and residual properties of thin-gage sheet material.

Oxidation coupons were exposed both continuously and cyclicly at 1033 K and 1256 K (1400° F and 1800° F) for exposure times extending to 5000 hours. Loss in effective sheet thickness for these coupons after extended exposures was found to be severe for the superalloys, with only the dispersion stabilized TD NiCr alloy (20 percent chromium) exhibiting good oxidation properties.

The creep behavior of the superalloys was obtained at 1033 K (1400° F) and selected alloys at 1145 K and 1256 K (1600° F and 1800° F). At the higher temperatures TD NiCr alloy exhibited the best creep resistance of the alloys investigated; however, rupture often occurred during the test at creep strains of less than 0.3 percent.

Room-temperature residual properties were determined on the creep specimens and also on specimens that were exposed to similar conditions but without stress. For thermal-protection-system applications above 1145 K (1600° F), Haynes No. 188 and TD NiCr appear to offer the best potential.

## INTRODUCTION

Superalloys are being considered for the primary heat shields and supports in the thermal protection system of both hypersonic-transport and space-shuttle vehicles (refs. 1 and 2). These classes of vehicles have different flight requirements which dictate the

environmental conditions that should be imposed on the candidate alloys in screening tests to determine the stability of material properties. The hypersonic transport has a proposed cruising speed of Mach 8 at 30 km (100 000 ft), and the desired vehicle life is at least 10 000 flights. The space shuttle will be required to operate from subsonic to hypersonic velocities and at altitudes ranging from sea level to altitudes of approximately 122 km (400 000 ft) and beyond. Minimum refurbishment of thermal protection systems is desirable for at least 100 flights.

Since conservative design philosophy dictates designs based on residual material properties at the end of the service life, material characterization after exposure to the environmental conditions imposed by the flight requirements of these two classes of vehicle is needed on the candidate alloys. In addition, since proposed heat shields are fabricated from thin-gage materials, there is also a need for material property data on thin-gage superalloy sheet, as the available information in the literature is predominately on rod, bar, or plate material.

The present paper reports the results of an investigation at the Langley Research Center to provide some of the necessary data. The general program objectives of this investigation were to obtain oxidation, creep, and residual mechanical-property data on candidate superalloy sheet materials for thermal-protection-system applications for hypersonic-transport and space-shuttle vehicles. The effects of sheet thickness, static air pressure, stress, and temperature on creep and residual mechanical properties were examined on selected alloys. Results of creep behavior, residual mechanical properties, and metallurgical examination were related to fabrication history and test environment.

The units used for the physical quantities defined in this paper are given both in the U.S. Customary Units and in the International System of Units (SI). Measurements and calculations were made in the U.S. Customary Units. Factors relating the two systems are given in reference 3, and those used in the present investigation are presented in the appendix.

## MATERIALS AND SPECIMENS

### Materials

Previous studies (refs. 4, 5, and 6) have shown that elevated-temperature oxidation resistance, creep resistance, and strength are significant properties for heat-shield design. Thus, the alloys in the present investigation were selected with emphasis on these properties. A description of the selected sheet materials and heat treatments is given in table I. The alloys were tested in the solution-treated conditions. No tests were conducted on materials in the various aged conditions as it was felt the subsequent high-temperature exposure would have negated these optimized treatments. The superalloys in the investigation were: commercially available nickel-base alloys, René 41,

Hastelloy X, Inconel 625, and Inconel 718; and cobalt-base alloys, Haynes No. 25 and Haynes No. 188. The dispersion stabilized TD NiCr alloy was not in the same development status as the other alloys, but was included in the investigation because of its reported excellent material properties at temperatures exceeding those where conventional superalloys can be used. The nominal chemical composition of the sheet materials investigated is given in table II.

## Specimens

The specimen configurations utilized in this investigation are shown in figure 1. All creep and residual-strength specimens were tested in the longitudinal direction of the sheets. All specimens from each alloy of the same sheet thickness were made from the same heat but not necessarily the same sheet. A gradual taper, small enough not to affect the creep behavior, was machined into the reduced section of the test specimens as described in reference 7 for the purposes of inducing the fracture to occur in the center portion of the specimens and to prevent undercutting in the test section.

Oxidation specimens were fabricated by cold shearing from the same sheets of material that were used in making the tensile specimens.

# PROCEDURES

The specimens were thoroughly cleaned before high-temperature exposure. The cleaning procedure consisted of removing markings, such as crayon or manufacturer's stamp, with acetone. The specimens were then alkaline cleaned followed, in order, by a cold water rinse, a hot water rinse, a nitric-acid dip, a hot water rinse, and a cold water rinse. The specimens were then dried by a small portable electrically heated air gun which heated the specimens to approximately 325 K ($130^{\circ}$ F). They were packaged in clean containers and thereafter handled with cotton gloves.

## Oxidation Tests

Continuous tests.- Continuous oxidation tests were made in air at 1.0664 $kN/m^2$ (8 torr) in a hot-wall vertical-tube furnace at 1033 K and 1256 K ($1400^{\circ}$ F and $1800^{\circ}$ F). Prior to exposure each specimen was weighed and measured. The specimens were then suspended in the furnace using platinum wire and exposed for preselected exposure times extending to 5000 hours. There was no evidence of platinum evaporation and/or deposition on test specimens after exposure. Dry air at a dewpoint of 233 K ($-40^{\circ}$ F) was circulated through the furnace during the exposure.

Cyclic tests.- Cyclic oxidation tests were made in dry air at a pressure of 0.1333 $kN/m^2$ (1 torr) in a vertical-tube furnace that was modified for automated cyclic

oxidation studies. Test specimens were suspended in the furnace chamber from platinum wire. After insertion of the specimens the test cycle consisted of evacuating the chamber to 0.1333 kN/m$^2$ (1 torr) followed by heating of the specimens to the desired test temperature. The specimens were soaked for one-half hour at temperature after which they were air cooled until ambient pressure was reached. Specimens were then further cooled to 220 K (-65$^\circ$ F) with dry nitrogen and allowed to return to room temperature for one-half hour before the next cycle began. The cycle was continued until accumulated exposures at temperature reached 100 hours. Prior to exposure the specimens were weighed and measured.

## Creep Tests

Tensile creep tests were made at 1033 K, 1145 K, and 1256 K (1400$^\circ$ F, 1600$^\circ$ F, and 1800$^\circ$ F) at an air pressure of 0.1333 or 1.0664 kN/m$^2$ (1 or 8 torr) over a range of stresses from 20.7 to 275.8 MN/m$^2$ (3 to 40 ksi). The creep tests were performed in constant-load creep machines equipped with vertical-tube vacuum retort furnaces which heated the test section of the specimens uniformly to within 3 K (5$^\circ$ F) of the nominal test temperatures, as measured by thermocouples mechanically attached to the specimens. New thermocouples were utilized for each specimen tested. In each furnace, two specimens were tested in tandem and the strains in each specimen were measured optically by sighting through ports in the wall of the furnace with a microscope and reading fiducial marks on platinum strips that were mechanically attached to the test specimens. Load was applied after the desired test temperature and pressure were obtained, approximately 2 to 3 hours from initial application of heat and one-half hour after stable test temperature was reached. Creep measurements were made immediately after onset of loading and at selected intervals thereafter until a creep strain of 0.5 percent was obtained at which time the test was terminated. The filar unit on the microscope used to make the creep measurements was graduated into minimum units of 0.5 $\mu$m (20 $\mu$in.) with reproducibility of readings being approximately ±1.5 $\mu$m (60 $\mu$in.).

## Residual-Property Tests

Room-temperature residual-property determinations were made from the creep test specimens and from specimens exposed to the same conditions of temperature and pressure without stress. The unstressed specimens were exposed continuously for preselected exposure times extending to 5000 hours at 1033 K and 1256 K (1400$^\circ$ F and 1800$^\circ$ F). All specimens were tensile tested to rupture at conventional strain rates of 0.005 per minute to the yield stress and at an increased test-machine head speed corresponding to a strain rate of 0.05 per minute from yield to rupture. Foil-type strain gages were used to measure strains. The tests were conducted in a 530.0-kN (120-kip) capacity hydraulic testing machine.

### Metallurgical Investigation

Electron probe microanalysis, scanning electron microscopy (SEM) of fracture surfaces, and metallographic and SEM examination of polished cross sections were conducted on both unexposed and exposed oxidation and creep specimens. These procedures were utilized to characterize microstructure, determine grain size, and correlate residual properties of specimens with basic material changes due to oxidation and creep of the superalloys. Grain-size determinations for as-received material can be found in table I.

Oxidation specimens.- After exposure oxidation specimens were sectioned, mounted on edge in bakelite, and polished using standard metallographic techniques. Loss in effective sheet thickness was measured optically on a metallograph using a filar micrometer eyepiece with a minimum unit of 0.076 $\mu$m (3 $\mu$in.) with reproducibility of readings being approximately $\pm$0.38 $\mu$m ($\pm$15 $\mu$in.). Additional metallographic examination was made in order to determine the microstructural changes which occurred during the environmental exposure associated with the oxidation process. This examination was conducted on specimens which were etched to reveal microstructural detail.

Creep and residual-property specimens.- Fracture surfaces of failed creep and residual-strength specimens were examined using SEM in order to determine the modes that controlled fracture behavior of the various alloys investigated.

## RESULTS AND DISCUSSION

### Oxidation Tests

Degradation of mechanical or creep properties can be related to the loss in effective sheet thickness which occurs as a result of general oxidation, grain boundary oxidation, or loss by diffusion of strengthening precipitates in bands adjacent to the unaffected substrate during high-temperature exposure in air. In determining the effective sheet thickness or loss in effective sheet thickness, one must take into account the mechanical or physical property which is being considered. While loss of strengthening precipitates may be expected to have little or no effect on the elastic modulus or room-temperature ultimate strength, it would be expected to have a significant effect on a high-temperature property such as creep resistance. Because the materials included in this investigation are primarily considered for high-temperature application where the design controlling limitation is sometimes creep resistance, bands in which strengthening precipitates are dissolved by a diffusion process at high temperature are also considered effectively lost for purposes of resisting creep strains. The loss in effective sheet thickness for the purpose of this investigation was determined by sectioning the specimens after exposure and measuring the residual thickness of unaffected substrate by optical means. The photomicrographs shown in figure 2 for René 41, Haynes 188, and TD NiCr after the noted

exposure conditions demonstrate the importance of a metallurgical examination to ascertain a correct assessment of the oxidation damage associated with high-temperature exposure. Both the René 41 and Haynes 188 alloys show substantial loss in effective sheet thickness. The exposure of 100 hours at 1256 K (1800° F) and 1.0664 $kN/m^2$ (8 torr) pressure affected 35 percent of the 0.508-mm (0.020-in.) sheet cross section and 57 percent of the 0.254-mm (0.010-in.) sheet cross section for René 41. For the TD NiCr specimens shown in figure 2, loss in effective sheet thickness results from internal oxidation manifested by the formation of chrome oxide $(Cr_2O_3)$ or spinel particles and voids in the material. The particles and voids are randomly distributed through the cross section for this particular severe exposure of 200 hours at 1478 K (2200° F) and 101.3 $kN/m^2$ (760 torr). The formation of voids in the material can be even more severe at lower pressures because of increased volatilization of chrome oxides. This evaporation causes chromium depletion at the surface of the specimen and increased chromium diffusion outward from the internal areas of the sheet material. The region of void formation is limited to very near the surface for lower temperatures and/or shorter exposure times.

Continuous tests.- The loss in effective sheet thickness resulting from oxidation is given in table III for all the alloys investigated. The exposure time to 0.0508-mm (0.002-in.) loss in effective sheet thickness for tests at 1256 K (1800° F) and 1.0664 $kN/m^2$ (8 torr) pressure is shown in figure 3 for both 0.254-mm and 0.508-mm (0.010-in. and 0.020-in.) sheet. The alloys are arranged in a sequence of increasing oxidation resistance. The exposures to 5000 hours are a lower limit for the service life anticipated for a hypersonic transport. Due to gage limitations for this application, the time for a 0.0508-mm (0.002-in.) loss in effective sheet thickness was arbitrarily set as the criterion in the oxidation screening test. The bar graph shows that the dispersion stabilized TD NiCr alloy was greatly superior to any of the other alloys tested with respect to oxidation resistance. The loss in effective sheet thickness for TD NiCr was less than the detectable limit of 2.54 $\mu$m (100 $\mu$in.) after 5000 hours exposure. All other alloys tested exhibited exposure times of less than 1000 hours for a 0.0508-mm (0.002-in.) loss in effective sheet thickness with René 41 and Inconel 718 alloys exhibiting the poorest oxidation resistance at this particular temperature.

At 1033 K (1400° F) after 5000 hours exposure, the loss in effective sheet thickness for any alloy investigated was never more than 0.0254 mm (0.001 in.) (see table III). Photomicrographs of René 41, Haynes 188, and TD NiCr after the exposures noted in figure 4 at 1033 K (1400° F) show small bands adjacent to the external oxidation layer where dissolution of strengthening precipitates took place. In the TD NiCr alloy, chrome oxide $(Cr_2O_3)$ or spinel particles form as a result of oxygen diffusion inward which can be seen in the affected band. However, the high-temperature strength of the TD NiCr is not affected as the thorium oxide $(ThO_2)$ particles, which stabilize and block slip in the nickel-

chromium matrix thereby strengthening the alloy, are unaffected by the oxidation process and remain randomly distributed through the matrix.

There was not a significant difference in loss of effective sheet thickness for 0.254-mm (0.010-in.) specimens as compared to 0.508-mm (0.020-in.) specimens for any of the alloys (see fig. 3). It should be noted, however, that a 0.0508-mm (0.002-in.) loss in 0.254-mm (0.010-in.) material effectively reduces the substrate by 20 percent, whereas, the same 0.0508-mm (0.002-in.) loss in 0.508-mm (0.020-in.) material would result in a substrate decrease of only 10 percent showing the importance of a minimum-gage consideration for the applications under consideration.

Cyclic tests.- The loss in effective sheet thickness resulting from oxidation of the specimens subjected to half-hour cyclic exposures is given in table IV. The loss in effective sheet thickness for a 100-hour accumulated exposure at 1256 K ($1800^{\circ}$ F) for 0.1333 kN/m$^2$ (1 torr) (cyclic and continuous data) and 1.0664 kN/m$^2$ (8 torr) (continuous data) air pressure is shown in figure 5 for René 41, Haynes 188, and TD NiCr on 0.508-mm (0.020-in.) sheet. The continuous data is reproduced from table III. The exposure time and reduced pressure are indicative of expected service required for a space-shuttle application. The TD NiCr alloy exhibited only a trace of loss in effective sheet thickness after 100 hours for all conditions tested. René 41 exhibited a loss of approximately 0.0508 mm (0.002 in.) for the continuous exposure while the Haynes 188 alloy lost from 0.0254 to 0.0386 mm (0.001 to 0.0015 in.) depending on the exposure condition. The effect of testing at two different pressure levels was not significant. There was a perceptible trend of cycled specimens showing a greater loss in effective sheet thickness than continuously exposed specimens.

On the basis of these results, the loss in effective sheet thickness because of oxidation may be a secondary factor in superalloy selection for space-shuttle application where exposures to 1256 K ($1800^{\circ}$ F) for 100 hours may be expected, although, for very thin-sheet applications, creep and residual properties may be seriously affected by the exposure. However, for other hypersonic vehicles with longer expected service lives, the alloy selection for heat shields with respect to oxidation is more critical. With a 0.0508-mm (0.002-in.) loss in effective sheet thickness as the selection criterion, only TD NiCr would be expected to survive 5000 hours exposure at 1256 K ($1800^{\circ}$ F).

## Creep Tests

The creep behavior was obtained on all the alloys at 1033 K ($1400^{\circ}$ F) and for selected alloys at 1145 K and 1256 K ($1600^{\circ}$ F and $1800^{\circ}$ F). The creep curves that were generated are shown in figures 6 to 12 and the data tabulated in table V. Generally, all tests were terminated after creep strains of 0.5 percent were attained. Creep curves generated on the Haynes 188 alloy are shown in figure 6. Figures 6(a) and 6(b) show the

creep curves for the Haynes 188 alloy at 1.0664 $kN/m^2$ (8 torr) pressure for 1033 K and 1256 K ($1400^{\circ}$ F and $1800^{\circ}$ F), respectively. Exposure stresses varied from 21 to 104 $MN/m^2$ (3 to 15 ksi) and the longest exposure was approximately 4000 hours. Figures 6(c) and 6(d) show the creep curves for the Haynes 188 alloy at 0.1333 $kN/m^2$ (1 torr) pressure for 1145 K and 1256 K ($1600^{\circ}$ F and $1800^{\circ}$ F), respectively. Exposure stresses varied from 21 to 55 $MN/m^2$ (3 to 8 ksi) with the longest exposure being 525 hours. The creep curves in figure 6 are indicative of what one would expect from material which behaves in a conventional manner with respect to creep. Similar curves were obtained for the other superalloys investigated (see figs. 7, 8, 9, 10, and 11).

The dispersion stabilized TD NiCr alloy exhibited creep curves somewhat different from the other materials tested. Creep curves for this alloy are shown in figure 12. Figures 12(a) and 12(b) show the creep curves for the TD NiCr material at 1.0664 $kN/m^2$ (8 torr) for 1033 K and 1256 K ($1400^{\circ}$ F and $1800^{\circ}$ F), respectively. At 1033 K ($1400^{\circ}$ F) *and the higher stresses tested, rupture occurred during the creep test at measured strains* of less than 0.3 percent except for one test on the 0.254-mm (0.010-in.) sheet. However, at the lower stresses tested, there appears to be a stress threshold below which little or no creep occurred after the first stage and the creep curves were nearly flat in the second stage as shown in figure 12(a). At 1033 K ($1400^{\circ}$ F) this threshold stress is approximately 104 $MN/m^2$ (15 ksi). At 1256 K ($1800^{\circ}$ F) (fig. 12(b)), where the creep strains prior to rupture were, in most cases, less than 0.2 percent, the threshold stress is approximately 34 $MN/m^2$ (5 ksi). Figures 12(c) and 12(d) show the creep curves for the TD NiCr alloy at 0.1333 $kN/m^2$ (1 torr) for 1145 K and 1256 K ($1600^{\circ}$ F and $1800^{\circ}$ F), respectively. With few exceptions, these tests were also terminated by rupture at creep strains of approximately 0.3 percent.

The low elongation characteristics at elevated temperatures have been a continuing problem in the development of this alloy (TD NiCr) and efforts are being made to improve ductility at higher temperatures through thermomechanical treatments. Since the TD NiCr material is still in the development state, current production sheet of this alloy may have somewhat different properties than those reported herein.

The effect of sheet thickness on creep resistance was investigated and typical results are shown in figure 13 for René 41, Haynes 188, and TD NiCr. The exposure time in hours to obtain the creep strains noted at the bottom of each bar graph series (0.2-percent strain for René 41 and Haynes 188 and 0.1-percent strain for TD NiCr) is shown at 1033 K ($1400^{\circ}$ F) for both 0.254-mm and 0.508-mm (0.010-in. and 0.020-in.) sheet thickness. For both René 41 and Haynes 188 alloys at 1033 K ($1400^{\circ}$ F), the 0.254-mm (0.010-in.) sheet has markedly lower creep resistance than the 0.508-mm (0.020-in.) sheet, particularly for the René 41 alloy where the difference is an order of magnitude. The TD NiCr material exhibited only slight differences in creep resistance between the 0.254-mm and 0.508-mm (0.010-in. and 0.020-in.) sheet.

In an effort to explain the difference in creep resistance between the two different thicknesses for each of the alloys, polished specimens were examined using SEM including energy dispersive X-ray chemical analyses in selected locations. Figure 14 shows photomicrographs and concentration levels at certain locations as marked for specimens of René 41 in the as-received condition and after exposure to the conditions noted. In figure 14(a), the microstructural appearance of the René 41 in the as-received, solution-treated condition is shown. Marked on the photomicrograph are the locations at which the chemical analyses in the accompanying table were conducted. The chemical-concentration-level numbers are uncorrected values for concentration, normalized to (i.e., divided by) the nominal chemical composition of the alloy for each element. It can be noted from the photomicrograph and the concentration levels that composition of the primary carbides does vary, with the major carbide forming elements present in various concentrations. However, the concentration of alloying elements is relatively constant in the matrix even in areas immediately adjacent to precipitates with no apparent depletion in the matrix observed. Note also that primary carbides are randomly located within the grains with no appreciable concentration of precipitates in the grain boundaries. Figure 14(b) shows appearance and composition at selected locations of a specimen after 100 hours at 1033 K (1400° F). Not much change has occurred in microstructural appearance. Primary carbides are still randomly located and chromium depletion is confined to an extremely small area immediately adjacent to the outer oxide (location D). After 1000 hours of exposure at 1033 K (1400° F) (fig. 14(c)), outer oxide formation (location G) is much heavier, grain boundary oxidation has occurred to much deeper penetration, and chromium depletion extends to a depth of approximately 25 $\mu$m (0.001 in.). In addition, primary carbides are concentrated in the grain boundaries throughout the thickness, except for a region adjacent to the surface. In addition, coarsening of the matrix suggests significant aging has occurred during the exposure. Figure 14(d) shows the appearance of a specimen after exposure at 1256 K (1800° F) for 100 hours. At this temperature, significant microstructural changes have occurred. The heavy outer oxide is apparent and results of grain boundary oxidation are evident just beyond the outer oxide (location A). Chromium depletion has occurred to a depth of approximately 50 $\mu$m (0.002 in.) and along this depth inward Kirkendall porosity resulting from chromium diffusion outward is evident (see insert).

Based on these results, the difference in creep resistance observed at 1033 K (1400° F) between different thicknesses of material cannot be attributed to oxidation damage or to depletion of strengthening alloying elements, as insignificant amounts of this type of damage have occurred at this temperature for exposures to 100 hours. Nor can the difference be attributed to a grain-size effect as little difference in grain size or grain growth was noted for exposures to 100 hours at 1033 K (1400° F). The results do support, however, an explanation of the behavior from an energy standpoint. The 0.254-mm (0.010-in.) thick specimen in the solution-treated condition might be expected to contain

larger amounts of distortional energy available to assist a creep mechanism, before a stable structure is reached during exposure. The fact that little sheet-thickness effect was observed at 1256 K ($1800^{\circ}$ F) was probably due to the fact that stabilization can occur extremely rapidly and not confound the creep process. The fact that René 41, a highly heat-treatable superalloy, was most significantly affected also supports this explanation, and suggests that a stabilization treatment or age would have reduced the gage effect observed at the 1033 K ($1400^{\circ}$ F) exposures.

Of the conventional superalloys investigated, René 41 at 1033 K and 1145 K ($1400^{\circ}$ F and $1600^{\circ}$ F) exhibits the highest resistance to creep, and at 1256 K ($1800^{\circ}$ F) Haynes 188 has the best creep resistance. However, all the alloys exhibited 0.005 strains at exposure times considerably shorter than the expected service life of a hypersonic transport vehicle. The alloy TD NiCr has the best creep resistance of all the alloys at 1145 K to 1256 K ($1600^{\circ}$ F to $1800^{\circ}$ F). However, as stated before, stress rupture occurred at low creep strains, usually less than 0.3 percent, indicating that the high-temperature ductility of this alloy is poor.

## Residual-Property Tests

It is anticipated that design allowables for the metallic thermal protection systems of space-shuttle and hypersonic aircraft will be based on material properties obtained under test conditions representative of the total exposure life associated with the vehicles. This means that design of metallic heat shields should be based upon residual properties of the materials during the last cycle of their expected cyclic service life. Results of residual property determinations for all the alloys investigated are tabulated in tables VI, VII, and VIII. Table VI gives the material properties of all the alloys before exposure, table VII gives the residual material properties of all the alloys after creep tests, and table VIII gives the residual material properties of all the alloys exposed at 1033 K and 1256 K ($1400^{\circ}$ F and $1800^{\circ}$ F) but without stress. Selected results are shown for the Haynes 188 alloy in figure 15. The exposure conditions are as noted beneath each bar graph series for 1033 K and 1256 K ($1400^{\circ}$ F and $1800^{\circ}$ F) exposures and properties are a percentage of the as-received specimens. Included in the figure with the creep specimens are tests on unstressed specimens which were exposed for times and temperature similar to those for the stressed specimens. Each bar graph is an average of two tests. There was some reduction in ultimate and yield strengths as compared to the as-received specimens and at 1256 K ($1800^{\circ}$ F) this reduction approaches 20 percent. The elongation, however, showed a much larger decrease with exposure, approaching one-third of the as-received elongation of 49 percent. Little difference was observed in the properties determined on specimens which had been exposed with and without stress for similar times. However, the longer exposure (500 to 1200 hours) affected elongation much more than the 50-hour exposure.

The decrease in elongation can be correlated with the appearance of the fracture surface shown in figure 16. Shown in the figure are SEM fractographs of specimens both before and after exposure for 0.508-mm (0.020-in.) thick material at low and high magnification. The fractographs show that the fracture mode changes gradually from a ductile, dimple-type rupture where the dimples initiate and grow from strengthening particles of which some are visible (see fig. 16(a)), to a mixed dimple/intergranular rupture (fig. 16(b)), to predominately intergranular rupture (fig. 16(c)) with increased exposure time. This indicates that with increasing exposures, fracture characteristics are being governed primarily by grain boundary behavior.

Selected results of the residual property determinations for René 41 are shown in figure 17. For the 1033 K (1400° F) data, an overall increase in strength due to aging of the material during exposure is noted. The René 41 was obtained in the solution-treated condition and was not aged prior to testing. The data at 1256 K (1800° F) indicate that the material has overaged as a result of the exposure, and the room-temperature residual-strength properties are reduced from those specimens exposed at 1033 K (1400° F). However, 1256 K (1800° F) appears to be somewhat higher than that at which the René 41 alloy should be used in extended service because of its rapid oxidation. Elongation after exposure at all temperatures investigated were lower than those observed on as-received specimens.

The decrease in elongation can again be correlated with the appearance of the fracture surface shown in figure 18. Shown in the figure are SEM fractographs of specimens both before and after exposure for 0.508-mm (0.020-in.) thick material at low and high magnifications. The fractographs show that the fracture mode changes from ductile, dimple-type rupture (see fig. 18(a)) to an entirely intergranular rupture (figs. 18(b) and 18(c)) after exposure at temperature and stress. The primary cause for this change in fracture mode lies in the precipitation of primary carbides along grain boundaries associated with the aging phenomena and not in the oxidation process. This is supported both by metallographic examination and by the fact that both 0.254-mm (0.010-in.) and 0.508-mm (0.020-in.) thick material exhibited similar behavior.

Results of selected residual property determinations on TD NiCr alloy are shown in figure 19. The data represent an average of two tests except for the ultimate strength and elongation properties of the creep specimens where the results warrant showing the actual data. The creep specimens at 1033 K and 1256 K (1400° F and 1800° F) exhibited reductions and scatter in ultimate strength and elongation which were not observed for specimens exposed without stress. This points out the extreme sensitivity to prior strain history of this material. The unstressed specimens show little or no effect due to the exposures. Photomicrographs of polished sections and SEM fractographs of fracture surfaces of specimens after residual property testing are shown in figure 20 for TD NiCr.

Visible in figure 20(a) is the fact that fracture in the 0.254-mm (0.010-in.) thick material is primarily intergranular as can be seen from comparing grain boundaries of the polished section with the scanning electron microscope fractograph. Fracture mode in the 0.508-mm (0.020-in.) thick material (fig. 20(b)) appears to be more interlaminar with the fracture occurring along chrome oxide stringers which are visible in the polished section. The oxide stringers are a result of the fabrication process and were evident in the 0.508-mm (0.020-in.) thick material prior to exposure.

## CONCLUDING REMARKS

The investigation described herein screened certain properties of superalloys considered applicable for thermal protection systems of both hypersonic-transport and space-shuttle vehicles. Particular emphasis in the investigation was placed on oxidation, creep, and residual properties of sheet materials.

With respect to sheet thickness for the applications considered, oxidation effects were of the same magnitude on the two sheet thicknesses tested – 0.254 mm (0.010 in.) and 0.508 mm (0.020 in.). Metallurgical examination of oxidation specimens indicated the depth to which damage had occurred. The effect of oxidation damage is particularly important in thin-gage sheet application as an increasing proportion of cross section is affected as gage thickness decreases. There was a significant effect on creep properties. Differences observed in creep for the two sheet thickness at the higher test temperature were due to the oxidation damage affecting proportionally a larger part of the cross section of the thinner sheet. Differences observed in creep for the two sheet thickness at the lower test temperature were considered more a function of material condition and were apparently governed by an energy phenomenon.

For exposures at temperature/stress-level combinations selected from static strength considerations, all conventional superalloys exhibited 0.005 strains at exposure times considerably shorter than the expected service life of a hypersonic transport vehicle. The dispersion stabilized TD NiCr alloy had the best creep resistance of all the alloys investigated; however, rupture often occurred during exposure at creep strains of less than 0.005.

From elementary strength considerations including creep, the following observations are offered. Solution-treated René 41 appears to possess usable strength and reliable residual properties for application to 1145 K ($1600^{\circ}$ F). The Haynes No. 188 alloy appears to possess potential for use to 1256 K ($1800^{\circ}$ F). The loss in elongation

observed is predictable and sufficient elongation remains after long exposures to allow its utilization under these conditions. The TD NiCr alloy possesses potential for use at temperatures exceeding 1256 K (1800° F). However, development efforts to increase reproducibility and creep strain at rupture for this alloy should be continued.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., August 15, 1972.

# APPENDIX

## CONVERSION OF U.S. CUSTOMARY UNITS TO SI UNITS

The International System of Units (SI) was adopted by the Eleventh General Conference on Weights and Measures, Paris, in October 1960, in Resolution No. 12. (See ref. 3.) Conversion factors for the units used herein are given in the following tables:

| Physical quantity | U.S. Customary Unit | Conversion factor (a) | SI Unit (b) |
|---|---|---|---|
| Force | kip = 1000 lbf | $4.448 \times 10^3$ | newtons (N) |
| Length | in. | $2.54 \times 10^{-2}$ | meters (m) |
| Moduli and stress | ksi = 1000 $lbf/in^2$ | $6.895 \times 10^6$ | $newtons/meter^2$ ($N/m^2$) |
| Pressure | torr | $1.333 \times 10^2$ | $newtons/meter^2$ ($N/m^2$) |
| Temperature | $^oF$ | 5/9 (F + 459.67) | degrees kelvin (K) |

[a] Multiply value given in U.S. Customary Unit by conversion factor to obtain equivalent value in SI Unit.

[b] Prefixes to indicate multiples of units are as follows:

| Prefix | Multiple | Symbol |
|---|---|---|
| micro | $10^{-6}$ | $\mu$ |
| milli | $10^{-3}$ | m |
| centi | $10^{-2}$ | c |
| kilo | $10^3$ | k |
| mega | $10^6$ | M |
| giga | $10^9$ | G |

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TABLE I.- SUPERALLOY SHEET THICKNESSES AND HEAT TREATMENTS

| Alloy | Nominal sheet thickness, mm | (in.) | Grain size (av diam), mm | (in.) | Heat treatment (a) |
|---|---|---|---|---|---|
| Nickel-base alloys | | | | | |
| René 41 | 0.254 | (0.010) | 0.035 | (0.0014) | Solution treated |
| | .508 | ( .020) | .035 | ( .0014) | Solution treated |
| Hastelloy X | .254 | ( .010) | .035 | ( .0014) | Solution treated |
| | .508 | ( .020) | .120 | ( .0047) | Solution treated |
| Inconel 625 | .254 | ( .010) | .025 | ( .0010) | Solution treated |
| | .508 | ( .020) | .025 | ( .0010) | Solution treated |
| Inconel 718 | .254 | ( .010) | .035 | ( .0014) | Solution treated |
| | .508 | ( .020) | .035 | ( .0014) | Solution treated |
| Cobalt-base alloys | | | | | |
| Haynes 25 | 0.254 | (0.010) | 0.045 | (0.0018) | Solution treated |
| | .508 | ( .020) | .045 | ( .0018) | Solution treated |
| Haynes 188 | .254 | ( .010) | .035 | ( .0014) | Solution treated |
| | .508 | ( .020) | .035 | ( .0014) | Solution treated |
| Dispersion stabilized alloys | | | | | |
| TD NiCr | 0.254 | (0.010) | >0.200 | (>0.0079) | Stress relieved |
| | .508 | ( .020) | .070 | ( .0028) | Stress relieved |

[a] Solution treated per manufacturer's internal specification.

TABLE II.- CHEMICAL COMPOSITION OF THE SUPERALLOY SHEET MATERIAL

| Alloy designation | Chemical composition, percent by mass (a) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mn | Ti | Al | Cr | Mo | Fe | $ThO_2$ | W | Co | Ni |
| René 41 | 0.03 | 3.20 | 1.50 | 18.80 | 9.86 | 0.90 | --- | ---- | 10.85 | Bal. |
| Hastelloy X | .29 | --- | --- | 21.57 | 8.60 | 18.07 | --- | 0.45 | 1.05 | Bal. |
| Inconel 718 | .06 | .96 | .34 | 19.27 | 3.02 | 18.54 | --- | ---- | .06 | Bal. |
| Inconel 625 | .01 | .27 | .17 | 21.82 | 8.90 | 2.89 | --- | ---- | ---- | Bal. |
| Haynes 188 | 1.04 | --- | --- | 21.84 | --- | 1.45 | --- | 14.88 | Bal. | 20.84 |
| Haynes 25 | 1.42 | --- | --- | 20.38 | --- | 1.82 | --- | 14.62 | Bal. | 10.57 |
| TD NiCr | --- | --- | --- | 21.82 | --- | ---- | 2.50 | ---- | ---- | Bal. |

[a] Vendor-supplied information.

TABLE III.- SHEET-THICKNESS LOSS RESULTING FROM OXIDATION OF SPECIMENS EXPOSED CONTINUOUSLY IN AIR PRESSURE OF 1.0664 $kN/m^2$ (8 torr)

(a) SI Units (sheet-thickness loss in mm)

| Alloy | Sheet thickness, mm | Exposure in hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 100 | 200 | 400 | 650 | 1000 | 2000 | 3500 | 5000 |
| Temperature = 1256 K | | | | | | | | | | |
| René 41 | 0.254 | 0.0508 | 0.0635 | 0.0787 | 0.0864 | 0.1017 | 0.1170 | (a) | (a) | (a) |
| | .508 | .0457 | .0610 | .0736 | .0888 | .1017 | .1244 | 0.1830 | (a) | (a) |
| Hastelloy X | .254 | .0178 | .0254 | .0304 | .0279 | .0330 | .0585 | (a) | (a) | (a) |
| | .508 | .0152 | .0203 | .0304 | .0254 | .0330 | .0508 | .0584 | 0.0940 | (a) |
| Inconel 625 | .254 | .0127 | .0152 | .0203 | .0228 | .0304 | .0864 | .0432 | (a) | (a) |
| | .508 | .0127 | .0178 | .0279 | .0304 | .0330 | .0890 | .0457 | .0559 | 0.0711 |
| Inconel 718 | .254 | .0279 | .0406 | .0533 | .0660 | .0761 | .0432 | .1041 | (a) | (a) |
| | .508 | .0279 | .0304 | .0533 | .0610 | .0811 | .0559 | .0889 | .1193 | .1450 |
| Haynes 25 | .254 | .0178 | .0228 | .0304 | .0254 | .0356 | .0534 | .0559 | (a) | (a) |
| | .508 | .0203 | .0279 | .0304 | .0304 | .0482 | .0660 | .0838 | .0965 | .7870 |
| Haynes 188 | .254 | .0127 | .0203 | .0355 | .0508 | .0660 | .0761 | .0889 | .0990 | (a) |
| | .508 | .0152 | .0228 | .0406 | .0482 | .0610 | .0635 | .0685 | .0813 | .1017 |
| TD NiCr | .254 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| | .508 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| Temperature = 1033 K | | | | | | | | | | |
| René 41 | 0.254 | (b) | (b) | (b) | (b) | (b) | 0.0076 | 0.0107 | 0.0178 | 0.0228 |
| | .508 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0152 | .0203 |
| Hastelloy X | .254 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0152 | .0107 |
| | .508 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0152 | .0076 |
| Inconel 625 | .254 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0152 | .0076 |
| | .508 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0152 | .0076 |
| Inconel 718 | .254 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | .0076 | .0076 |
| | .508 | (b) | (b) | (b) | (b) | (b) | .0076 | .0076 | (b) | .0076 |
| Haynes 25 | .254 | (b) | (b) | (b) | (b) | (b) | .0076 | .0051 | .0107 | .0107 |
| | .508 | (b) | (b) | (b) | (b) | (b) | .0076 | (b) | .0127 | .0127 |
| Haynes 188 | .254 | (b) | (b) | 0.0076 | 0.0076 | 0.0076 | (c) | (c) | (c) | (c) |
| | .508 | (b) | (b) | .0076 | .0076 | .0107 | (c) | (c) | (c) | (c) |
| TD NiCr | .254 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| | .508 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |

[a] Oxidation penetrates entire cross section.
[b] No measurable sheet-thickness loss.
[c] Data not obtained.

TABLE III.- SHEET-THICKNESS LOSS RESULTING FROM OXIDATION OF SPECIMENS EXPOSED CONTINUOUSLY IN AIR PRESSURE OF 1.0664 $kN/m^2$ (8 torr) – Concluded

(b) U.S. Customary Units (sheet-thickness loss in inches)

| Alloy | Sheet thickness, in. | Exposure in hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 100 | 200 | 400 | 650 | 1000 | 2000 | 3500 | 5000 |
| Temperature = 1800° F | | | | | | | | | | |
| René 41 | 0.010 | 0.0020 | 0.0025 | 0.0031 | 0.0034 | 0.0040 | 0.0046 | (a) | (a) | (a) |
| | .020 | .0018 | .0024 | .0029 | .0035 | .0040 | .0049 | 0.0072 | (a) | (a) |
| Hastelloy X | .010 | .0007 | .0010 | .0012 | .0011 | .0013 | .0023 | (a) | (a) | (a) |
| | .020 | .0006 | .0008 | .0012 | .0010 | .0013 | .0020 | .0023 | 0.0037 | (a) |
| Inconel 625 | .010 | .0005 | .0006 | .0008 | .0009 | .0012 | .0034 | .0017 | (a) | (a) |
| | .020 | .0005 | .0007 | .0011 | .0012 | .0013 | .0035 | .0018 | .0022 | 0.0028 |
| Inconel 718 | .010 | .0011 | .0016 | .0021 | .0026 | .0030 | .0017 | .0041 | (a) | (a) |
| | .020 | .0011 | .0012 | .0021 | .0024 | .0032 | .0022 | .0035 | .0047 | .0057 |
| Haynes 25 | .010 | .0007 | .0009 | .0012 | .0010 | .0014 | .0021 | .0022 | (a) | (a) |
| | .020 | .0008 | .0011 | .0012 | .0012 | .0019 | .0026 | .0033 | .0038 | .0310 |
| Haynes 188 | .010 | .0005 | .0008 | .0014 | .0020 | .0026 | .0030 | .0035 | .0039 | (a) |
| | .020 | .0006 | .0009 | .0016 | .0019 | .0024 | .0025 | .0027 | .0032 | .0040 |
| TD NiCr | .010 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| | .020 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| Temperature = 1400° F | | | | | | | | | | |
| René 41 | 0.010 | (b) | (b) | (b) | (b) | (b) | 0.0003 | 0.0004 | 0.0007 | 0.0009 |
| | .020 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0006 | .0008 |
| Hastelloy X | .010 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0006 | .0004 |
| | .020 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0006 | .0003 |
| Inconel 625 | .010 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0006 | .0003 |
| | .020 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0006 | .0003 |
| Inconel 718 | .010 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | .0003 | .0003 |
| | .020 | (b) | (b) | (b) | (b) | (b) | .0003 | .0003 | 2.0000 | .0003 |
| Haynes 25 | .010 | (b) | (b) | (b) | (b) | (b) | .0003 | .0002 | .0004 | .0004 |
| | .020 | (b) | (b) | (b) | (b) | (b) | .0003 | (b) | .0005 | .0005 |
| Haynes 188 | .010 | (b) | (b) | 0.0003 | 0.0003 | 0.0003 | (c) | (c) | (c) | (c) |
| | .020 | (b) | (b) | .0003 | .0003 | .0004 | (c) | (c) | (c) | (c) |
| TD NiCr | .010 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| | .020 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |

[a] Oxidation penetrates entire cross section.

[b] No measurable sheet-thickness loss.

[c] Data not obtained.

TABLE IV.- SHEET-THICKNESS LOSS RESULTING FROM OXIDATION OF SPECIMENS EXPOSED CYCLICALLY AND CONTINUOUSLY IN AIR PRESSURE OF 0.1333 $kN/m^2$ (1 torr) AT 1256 K ($1800^{\circ}$ F)

(a) SI Units (sheet-thickness loss in mm)

| Alloy | Sheet thickness, mm | Exposure in hours | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 | 25 | 50 | 100 | 25 | 50 | 100 |
| | | Number of cycles | | | | (Continuous exposure) | | |
| | | 20 | 50 | 100 | 200 | | | |
| René 41 | 0.254 | 0.0356 | 0.0457 | 0.0533 | 0.0635 | 0.0406 | 0.0508 | 0.0610 |
| | .508 | .0330 | .0457 | .0533 | .0710 | .0406 | .0508 | .0585 |
| Hastelloy X | .254 | (a) | (a) | (a) | .0152 | (a) | .0152 | .0178 |
| | .508 | (a) | (a) | (a) | .0120 | (a) | (a) | .0203 |
| Haynes 25 | .254 | (a) | .0228 | .0254 | .0356 | (a) | .0228 | .0254 |
| | .508 | (a) | .0178 | .0356 | .0406 | (a) | .0279 | .0305 |
| Haynes 188 | .254 | (a) | (a) | .0228 | .0305 | (a) | .0203 | .0178 |
| | .508 | (a) | (a) | .0203 | .0305 | (a) | .0178 | .0228 |
| TD NiCr | .254 | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | .508 | (a) | (a) | (a) | (a) | (a) | (a) | (a) |

(b) U.S. Customary Units (sheet-thickness loss in inches)

| Alloy | Sheet thickness, in. | Exposure in hours | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 | 25 | 50 | 100 | 25 | 50 | 100 |
| | | Number of cycles | | | | (Continuous exposure) | | |
| | | 20 | 50 | 100 | 200 | | | |
| René 41 | 0.010 | 0.0014 | 0.0018 | 0.0021 | 0.0025 | 0.0016 | 0.0020 | 0.0024 |
| | .020 | .0013 | .0018 | .0021 | .0028 | .0016 | .0020 | .0023 |
| Hastelloy X | .010 | (a) | (a) | (a) | .0006 | (a) | .0006 | .0007 |
| | .020 | (a) | (a) | (a) | .0005 | (a) | (a) | .0008 |
| Haynes 25 | .010 | (a) | .0009 | .0010 | .0014 | (a) | .0009 | .0010 |
| | .020 | (a) | .0007 | .0014 | .0016 | (a) | .0011 | .0012 |
| Haynes 188 | .010 | (a) | (a) | .0009 | .0012 | (a) | .0008 | .0007 |
| | .020 | (a) | (a) | .0008 | .0012 | (a) | .0007 | .0009 |
| TD NiCr | .010 | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | .020 | (a) | (a) | (a) | (a) | (a) | (a) | (a) |

[a] No measurable sheet-thickness loss.

TABLE V. - RESULTS OF CREEP TESTS -

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 275.8 MN/M2 (40.0 KSI) | | |
| .00016 | | .5 |
| .00046 | | .6 |
| .00036 | | .7 |
| .00044 | | .9 |
| .00053 | | 1.1 |
| .00054 | | 1.3 |
| .00143 | | 17.0 |
| .00140 | | 18.4 |
| .00155 | | 19.4 |
| .00161 | | 20.3 |
| .00181 | | 23.1 |
| .00171 | | 24.6 |
| .00209 | | 25.3 |
| .00166 | | 41.0 |
| .00211 | | 46.3 |
| .00219 | | 48.9 |
| .00388 | | 113.0 |
| .00365 | | 117.2 |
| .00376 | | 120.7 |
| .00411 | | 137.0 |
| .00435 | | 140.2 |
| .00484 | | 145.4 |
| .00466 | | 161.0 |
| .00469 | | 165.2 |
| .00470 | | 169.0 |
| .00523 | | 185.4 |
| .00525 | | 188.6 |
| .00538 | | 193.0 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 205.8 MN/M2 (30.0 KSI) | | |
| -.00047 | | .2 |
| .00035 | | 1.6 |
| -.00027 | | 2.9 |
| -.00039 | | 19.0 |
| 0.00000 | | 22.8 |
| .00074 | | 26.8 |
| .00079 | | 42.9 |
| .00078 | | 46.7 |
| .00174 | | 66.9 |
| .00128 | | 70.1 |
| .00140 | | 74.8 |
| .00125 | | 91.0 |
| .00132 | | 94.7 |
| .00181 | | 163.0 |
| .00079 | | 187.0 |
| .00051 | | 211.0 |
| .00076 | | 235.0 |
| .00080 | | 259.0 |
| .00165 | | 331.0 |
| .00208 | | 355.0 |
| .00221 | | 379.0 |
| .00221 | | 403.0 |
| .00252 | | 427.0 |
| .00359 | | 499.0 |
| .00391 | | 523.0 |
| .00407 | | 547.0 |
| .00454 | | 571.0 |
| .00446 | | 595.0 |
| .00509 | | 667.0 |
| .00596 | | 675.0 |
| STRESS - 205.8 MN/M2 (30.0 KSI) | | |
| | -.00075 | .2 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 206.8 MN/M2 (30.0 KSI) | |
| | .00075 | 1.6 |
| | .00104 | 2.9 |
| | .00204 | 19.0 |
| | .00206 | 22.8 |
| | .00174 | 26.8 |
| | .00236 | 42.9 |
| | .00257 | 46.7 |
| | .00227 | 66.9 |
| | .00261 | 70.1 |
| | .00209 | 74.8 |
| | .00234 | 91.0 |
| | .00170 | 94.7 |
| | .00284 | 163.0 |
| | .00180 | 187.0 |
| | .00215 | 211.0 |
| | .00239 | 235.0 |
| | .00250 | 259.0 |
| | .00289 | 331.0 |
| | .00315 | 355.0 |
| | .00375 | 379.0 |
| | .00392 | 403.0 |
| | .00451 | 427.0 |
| | .00541 | 499.0 |
| | .00567 | 523.0 |
| | .00612 | 547.0 |
| | .00694 | 571.0 |
| | .00734 | 595.0 |
| | .00839 | 667.0 |
| | .00889 | 675.0 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 137.9 MN/M2 (20.0 KSI) | |
| .00017 | | .2 |
| .00019 | | .7 |
| .00032 | | 1.7 |
| .00049 | | 5.9 |
| .00061 | | 25.7 |
| .00048 | | 30.0 |
| .00100 | | 71.8 |
| .00041 | | 79.2 |
| .00073 | | 94.8 |
| .00102 | | 167.7 |
| .00134 | | 262.7 |
| .00164 | | 334.5 |
| .00152 | | 432.7 |
| .00177 | | 531.6 |
| .00199 | | 601.1 |
| .00224 | | 627.0 |
| .00208 | | 648.5 |
| .00219 | | 676.3 |
| .00195 | | 701.0 |
| .00241 | | 767.5 |
| .00253 | | 797.6 |
| .00259 | | 821.2 |
| .00255 | | 867.5 |
| .00260 | | 936.5 |
| .00279 | | 959.8 |
| .00287 | | 985.5 |
| .00287 | | 1012.2 |
| .00321 | | 1031.6 |
| .00294 | | 1107.6 |
| .00296 | | 1131.1 |
| .00323 | | 1155.9 |
| .00302 | | 1180.5 |
| .00371 | | 1200.2 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| .00341 | | 1275.6 |
| .00380 | | 1302.1 |
| .00365 | | 1321.8 |
| .00407 | | 1348.9 |
| .00390 | | 1367.6 |
| .00412 | | 1440.9 |
| .00437 | | 1516.3 |
| .00432 | | 1540.3 |
| .00459 | | 1617.3 |
| .00449 | | 1636.1 |
| .00451 | | 1660.3 |
| .00474 | | 1684.6 |
| .00473 | | 1708.4 |
| .00452 | | 1780.0 |
| .00488 | | 1805.7 |
| .00497 | | 1852.1 |
| .00499 | | 1876.4 |
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| | .00004 | .3 |
| | .00022 | .6 |
| | .00047 | 1.7 |
| | .00051 | 5.9 |
| | .00077 | 25.7 |
| | .00073 | 71.8 |
| | .00071 | 79.2 |
| | .00095 | 94.8 |
| | .00102 | 167.7 |
| | .00155 | 262.7 |
| | .00194 | 334.5 |
| | .00204 | 432.7 |
| | .00200 | 531.6 |
| | .00212 | 601.1 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| | .00224 | 627.0 |
| | .00252 | 648.5 |
| | .00278 | 675.3 |
| | .00263 | 701.0 |
| | .00234 | 767.5 |
| | .00222 | 787.6 |
| | .00287 | 821.2 |
| | .00257 | 867.5 |
| | .00311 | 936.5 |
| | .00321 | 959.3 |
| | .00321 | 985.5 |
| | .00325 | 1012.2 |
| | .00335 | 1031.6 |
| | .00373 | 1107.6 |
| | .00349 | 1131.1 |
| | .00379 | 1155.9 |
| | .00383 | 1180.5 |
| | .00366 | 1200.2 |
| | .00382 | 1275.6 |
| | .00412 | 1302.1 |
| | .00403 | 1321.8 |
| | .00393 | 1348.9 |
| | .00415 | 1367.6 |
| | .00410 | 1440.9 |
| | .00454 | 1516.3 |
| | .00476 | 1540.3 |
| | .00493 | 1613.3 |
| | .00472 | 1636.1 |
| | .00519 | 1660.3 |
| | .00513 | 1684.6 |
| | .00492 | 1708.4 |
| | .00563 | 1780.0 |
| | .00596 | 1805.7 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| | .00581 | 1852.1 |
| | .00603 | 1876.4 |
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| -.00016 | .00002 | .5 |
| -.00012 | .00041 | 2.5 |
| -.00012 | .00053 | 19.4 |
| 0.00000 | .00042 | 26.5 |
| -.00002 | .00040 | 49.3 |
| .00084 | .00149 | 187.7 |
| .00004 | .00092 | 234.7 |
| .00058 | .00110 | 357.8 |
| .00078 | .00136 | 481.9 |
| .00070 | .00122 | 673.9 |
| .00090 | .00132 | 724.8 |
| .00111 | .00138 | 868.0 |
| .00133 | .00142 | 936.5 |
| .00133 | .00192 | 1083.7 |
| .00136 | .00182 | 1204.0 |
| .00133 | .00167 | 1439.6 |
| .00263 | .00186 | 1566.0 |
| .00186 | .00372 | 1635.9 |
| .00336 | .00357 | 1799.0 |
| .00304 | .00360 | 1872.3 |
| .00332 | .00342 | 2044.3 |
| .00274 | .00305 | 2134.8 |
| .00282 | .00313 | 2207.1 |
| .00282 | .00290 | 2376.5 |
| .00309 | .00294 | 2540.9 |
| .00342 | .00322 | 2734.5 |
| .00342 | .00328 | 2906.4 |
| .00351 | .00322 | 3049.2 |
| .00361 | .00332 | 3242.0 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00374 | .00402 | 3381.7 |
| .00384 | .00375 | 3552.4 |
| .00398 | .00369 | 3741.2 |
| .00412 | .00382 | 3912.4 |
| .00441 | .00400 | 4106.2 |
| .00478 | .00410 | 4250.5 |
| .00485 | .00432 | 4393.8 |
| .00488 | .00435 | 4560.5 |
| .00490 | .00452 | 4752.9 |
| .00498 | .00456 | 4896.4 |
| .00504 | .00464 | 5063.4 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 172.4 MN/M2 (25.0 KSI) | |
| -.00020 | .00010 | .2 |
| -.00005 | .00015 | .3 |
| .00002 | .00022 | .4 |
| .00007 | .00006 | .5 |
| .00003 | .00006 | .6 |
| 0.00000 | .00005 | 1.1 |
| 0.00000 | .00011 | 2.2 |
| .00006 | 0.00000 | 3.1 |
| .00009 | .00054 | 19.2 |
| .00040 | .00085 | 26.8 |
| .00074 | .00102 | 50.6 |
| .00140 | .00161 | 74.5 |
| .00300 | .00347 | 169.8 |
| .00396 | .00838 | 312.6 |
| STRESS - | 137.9 MN/M2 (20.0 KSI) | |
| .00006 | -.00007 | .3 |
| .00008 | .00059 | .4 |
| .00030 | .00065 | 1.5 |
| .00053 | .00183 | 22.6 |
| .00143 | .00198 | 49.2 |
| .00206 | .00250 | 70.8 |
| .00317 | .00337 | 138.4 |
| .00348 | .00331 | 169.4 |
| .00416 | .00352 | 193.5 |
| .00464 | .00424 | 237.5 |
| .00500 | .00526 | 316.0 |

MATERIAL - RENE 41
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| -.00040 | 0.00000 | .2 |
| -.00010 | 0.00000 | .3 |
| -.00060 | .00020 | .6 |
| -.00056 | 0.00000 | 2.1 |
| -.00060 | .00050 | 18.3 |
| -.00020 | .00075 | 24.2 |
| .00035 | .00114 | 42.3 |
| .00040 | .00135 | 49.9 |
| .00100 | .00186 | 114.7 |
| .00110 | .00278 | 162.3 |
| .00140 | .00303 | 210.3 |
| .00240 | .00415 | 282.3 |
| .00250 | .00472 | 306.6 |
| .00260 | .00485 | 330.4 |
| .00300 | .00578 | 385.4 |
| .00322 | .00635 | 450.3 |
| .00356 | .00680 | 475.6 |
| .00360 | .00720 | 498.4 |
| .00379 | .00725 | 522.2 |
| .00400 | .00762 | 551.5 |
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| 0.00000 | .00006 | .2 |
| .00014 | .00004 | 2.0 |
| .00029 | -.00015 | 18.0 |
| .00052 | .00010 | 25.5 |
| .00114 | .00031 | 90.3 |
| .00110 | .00040 | 114.1 |
| .00120 | .00069 | 138.0 |
| .00064 | .00034 | 162.2 |
| .00061 | .00040 | 186.1 |
| .00156 | .00095 | 258.0 |
| .00155 | .00096 | 282.2 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00174 | .00105 | 306.2 |
| .00194 | .00120 | 361.0 |
| .00206 | .00154 | 426.1 |
| .00263 | .00140 | 451.3 |
| .00188 | .00150 | 474.1 |
| .00194 | .00158 | 527.2 |
| .00198 | .00138 | 601.0 |
| .00264 | .00203 | 697.5 |
| .00230 | .00192 | 864.8 |
| .00276 | .00250 | 933.7 |
| .00249 | .00265 | 1100.1 |
| .00303 | .00193 | 1308.9 |
| .00397 | .00294 | 1517.4 |
| .00322 | .00300 | 2131.2 |
| .00325 | .00331 | 2151.7 |
| .00317 | .00325 | 2472.4 |
| .00397 | .00457 | 2687.9 |
| .00453 | .00540 | 2974.5 |
| .00452 | .00545 | 3120.2 |
| .00450 | .00560 | 3334.5 |
| .00533 | .00706 | 3716.0 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00199 | .00340 | .5 |
| .00295 | .00521 | .7 |
| .00391 | .00805 | .9 |
| .00579 | .01257 | 1.3 |
| STRESS - 20.7 MN/M2 ( 3.0 KSI) | | |
| 0.00000 | .00024 | .4 |
| .00005 | .00034 | .6 |
| .00006 | .00064 | 1.4 |
| .00148 | .00464 | 2.8 |
| .00552 | .01080 | 19.4 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 63.9 MN/M2 (10.0 KSI) | |
| | .00062 | .2 |
| | .00100 | .3 |
| | .00162 | .4 |
| | .00203 | .5 |
| | .00266 | .6 |
| | .00305 | .7 |
| | .00374 | .8 |
| | .00985 | 1.6 |
| | .01070 | 1.7 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00006 | .00014 | .2 |
| .00014 | .00046 | .3 |
| .00036 | .00040 | .8 |
| .00039 | .00049 | 1.6 |
| .00072 | .00090 | 2.7 |
| .00300 | .00390 | 18.7 |
| .00444 | .00480 | 26.7 |
| .00700 | .00715 | 42.8 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| -.00017 | .00029 | .3 |
| -.00010 | .00036 | .4 |
| .00007 | .00042 | 1.7 |
| .00015 | .00090 | 4.0 |
| .00013 | .00160 | 5.7 |
| .00040 | .00378 | 21.7 |
| .00117 | .00458 | 27.0 |
| .00129 | .00505 | 29.5 |
| .00230 | .00800 | 45.8 |
| STRESS - | 82.7 MN/M2 (12.0 KSI) | |
| .00015 | 0.00000 | .3 |
| .00016 | -.00010 | 1.4 |
| .00012 | -.00005 | 3.3 |
| .00016 | -.00016 | 4.2 |
| .00079 | .00065 | 20.4 |
| .00156 | .00070 | 27.8 |
| .00650 | .00380 | 116.9 |
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00009 | .00053 | .3 |
| .00038 | .00058 | .5 |
| .00026 | .00032 | .9 |
| .00065 | .00033 | 2.0 |
| .00090 | .00027 | 3.9 |
| .00171 | .00174 | 21.9 |
| .00200 | .00234 | 28.9 |
| .00244 | .00335 | 45.6 |
| .00283 | .00380 | 53.0 |
| .00522 | .01000 | 117.5 |
| .00545 | .01096 | 125.1 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 62.1 MN/M2 ( 9.0 KSI) | |
| .00029 | .00062 | .5 |
| .00029 | .00062 | .5 |
| .00079 | .00072 | 1.5 |
| .00090 | .00053 | 3.8 |
| .00072 | .00061 | 4.6 |
| .00107 | .00120 | 20.5 |
| .00125 | .00150 | 27.5 |
| .00141 | .00164 | 45.5 |
| .00183 | .00192 | 52.4 |
| .00170 | .00296 | 76.6 |
| .00298 | .00510 | 141.0 |
| .00334 | .00638 | 164.6 |
| .00327 | .00674 | 172.5 |
| STRESS - | 58.6 MN/M2 ( 8.5 KSI) | |
| .00004 | .00007 | .3 |
| .00022 | .00015 | .4 |
| .00039 | .00012 | .6 |
| .00043 | .00020 | 1.0 |
| .00065 | .00018 | 2.4 |
| .00089 | .00014 | 3.8 |
| .00090 | .00022 | 5.2 |
| .00129 | .00014 | 21.3 |
| .00173 | .00009 | 29.1 |
| .00218 | .00108 | 45.3 |
| .00201 | .00127 | 53.0 |
| .00248 | .00205 | 76.8 |
| .00256 | .00230 | 100.8 |
| .00343 | .00402 | 173.3 |
| .00419 | .00530 | 213.8 |
| .00448 | .00625 | 245.2 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00010 | .00009 | .3 |
| .00018 | .00001 | .4 |
| -.00038 | .00003 | .8 |
| -.00016 | -.00008 | 1.6 |
| -.00022 | .00045 | 5.1 |
| -.00020 | .00030 | 20.7 |
| .00010 | .00135 | 28.9 |
| .00036 | .00156 | 45.9 |
| .00040 | .00143 | 52.5 |
| .00081 | .00234 | 68.7 |
| .00063 | .00214 | 76.8 |
| .00120 | .00275 | 110.0 |
| .00093 | .00286 | 114.4 |
| .00128 | .00362 | 137.1 |
| .00137 | .00439 | 161.7 |
| .00175 | .00479 | 178.4 |
| .00206 | .00455 | 202.4 |
| .00267 | .00730 | 274.4 |
| .00346 | .00906 | 298.6 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00033 | .00065 | .2 |
| .00032 | .00054 | .4 |
| .00038 | .00060 | .6 |
| .00035 | .00120 | 1.5 |
| .00103 | .00207 | 2.7 |
| .00570 | .01424 | 18.9 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00003 | .00004 | .2 |
| .00024 | .00055 | .4 |
| .00028 | .00075 | .5 |
| .00036 | .00164 | 2.0 |
| .00062 | .00243 | 4.0 |
| .00081 | .00280 | 4.8 |
| .00379 | .00782 | 21.0 |
| .00491 | .00979 | 26.4 |
| STRESS - | 13.8 MN/M2 ( 2.0 KSI) | |
| .00015 | .00038 | .3 |
| -.00002 | .00042 | .4 |
| -.00006 | .00079 | .5 |
| -.00006 | .00060 | .7 |
| .00042 | .00055 | .8 |
| .00018 | .00079 | 1.9 |
| .00029 | .00090 | 2.4 |
| .00042 | .00101 | 3.4 |
| .00076 | .00104 | 4.5 |
| .00047 | .00121 | 4.9 |
| .00138 | .00216 | 20.9 |
| .00214 | .00351 | 26.0 |
| .00220 | .00374 | 27.5 |
| .00233 | .00350 | 29.1 |
| .00380 | .00504 | 44.9 |

MATERIAL - RENE 41
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 13.8 MN/M2 ( 2.0 KSI) | |
| .00475 | .00599 | 52.5 |
| .00567 | .00852 | 69.0 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HASTELLOY X
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 137.9 MN/M2 | (20.0 KSI) |
| -.00104 | .00004 | 1.0 |
| .00013 | .00024 | 1.2 |
| .00028 | .00053 | 1.4 |
| .00099 | .00031 | 1.7 |
| .00069 | .00115 | 2.1 |
| .00125 | .00156 | 2.7 |
| .00138 | .00187 | 2.9 |
| .01489 | .01470 | 18.8 |
| .01624 | .01535 | 19.7 |
| .01719 | .01581 | 20.7 |
| .01830 | .01748 | 21.7 |
| .01924 | .01867 | 22.6 |
| .02093 | .02027 | 23.9 |
| .02091 | .02094 | 24.2 |
| STRESS - | 103.4 MN/M2 | (15.0 KSI) |
| -.00003 | .00033 | .2 |
| .00016 | .00051 | .5 |
| .00016 | .00055 | .7 |
| .00084 | .00088 | 2.7 |
| .00307 | .00342 | 19.1 |
| .00384 | .00346 | 22.6 |
| .00389 | .00497 | 26.9 |
| .00673 | .00717 | 43.2 |
| .00738 | .00762 | 46.1 |
| .00811 | .00878 | 50.9 |

MATERIAL - HASTELLOY X
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 68.9 MN/M2 | (10.0 KSI) |
| .00010 | .00061 | .2 |
| .00027 | .00071 | .5 |
| .00027 | .00062 | .7 |
| .00037 | .00081 | 1.3 |
| .00050 | .00082 | 2.1 |
| .00050 | .00111 | 18.2 |
| .00081 | .00123 | 26.2 |
| .00160 | .00274 | 66.5 |
| .00339 | .00582 | 167.3 |
| .00419 | .00790 | 183.1 |
| STRESS - | 51.7 MN/M2 | ( 7.5 KSI) |
| .00005 | | .2 |
| -.00006 | | .3 |
| -.00006 | | 1.2 |
| .00003 | | 2.7 |
| .00007 | | 19.1 |
| .00019 | | 22.8 |
| .00039 | | 27.0 |
| .00029 | | 43.2 |
| .00079 | | 48.1 |
| .00121 | | 51.0 |
| .00108 | | 67.0 |
| .00112 | | 72.1 |
| .00134 | | 74.6 |
| .00167 | | 139.0 |
| .00146 | | 143.0 |
| .00159 | | 147.0 |
| .00182 | | 163.0 |
| .00200 | | 166.6 |
| .00194 | | 172.2 |
| .00208 | | 187.0 |
| .00213 | | 190.6 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HASTELLOY X
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 51.7 MN/M2 ( 7.5 KSI) | | |
| .00241 | | 211.0 |
| .00220 | | 215.0 |
| .00210 | | 219.0 |
| .00229 | | 235.0 |
| .00237 | | 243.0 |
| .00223 | | 307.0 |
| .00221 | | 314.5 |
| .00208 | | 331.0 |
| .00258 | | 355.0 |
| .00324 | | 362.6 |
| .00319 | | 379.0 |
| .00283 | | 386.2 |
| .00292 | | 403.0 |
| .00352 | | 410.4 |
| .00343 | | 475.0 |
| .00339 | | 483.0 |
| .00380 | | 499.0 |
| .00367 | | 506.6 |
| .00362 | | 523.0 |
| .00393 | | 531.0 |
| .00363 | | 547.0 |
| .00394 | | 555.0 |
| .00402 | | 571.0 |
| .00385 | | 578.9 |
| .00431 | | 643.0 |
| .00407 | | 651.3 |
| .00470 | | 667.0 |
| .00411 | | 675.0 |
| .00479 | | 691.0 |
| .00500 | | 699.0 |
| .00501 | | 715.0 |
| .00454 | | 723.0 |
| .00460 | | 739.0 |

MATERIAL - HASTELLOY X
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 51.7 MN/M2 ( 7.5 KSI) | | |
| .00492 | | 747.0 |
| .00464 | | 811.0 |
| .00498 | | 818.9 |
| .00491 | | 835.0 |
| .00481 | | 843.1 |
| .00494 | | 859.0 |
| .00454 | | 867.2 |
| .00507 | | 883.0 |
| .00453 | | 891.0 |
| .00489 | | 907.0 |
| .00474 | | 914.7 |
| .00542 | | 979.0 |
| .00534 | | 986.0 |
| .00508 | | 1004.0 |
| .00528 | | 1029.0 |
| STRESS - 34.5 MN/M2 ( 5.0 KSI) | | |
| 0.00000 | .00003 | .2 |
| .00008 | .00021 | .4 |
| .00015 | .00025 | .8 |
| .00016 | .00034 | 1.8 |
| .00016 | .00086 | 2.8 |
| .00033 | .00056 | 18.6 |
| .00002 | .00073 | 26.1 |
| .00062 | .00077 | 50.6 |
| .00088 | .00130 | 119.7 |
| .00060 | .00140 | 286.6 |
| .00073 | .00130 | 457.9 |
| .00123 | .00200 | 626.1 |
| .00137 | .00200 | 794.2 |
| .00180 | .00220 | 986.7 |
| .00214 | .00263 | 1178.6 |
| .00215 | .00308 | 1393.5 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HASTELLOY X
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 34.5 MN/M2 ( 5.0 KSI) | | |
| .00228 | .00250 | 1538.2 |
| .00200 | .00297 | 1678.0 |
| .00262 | .00333 | 1845.8 |
| .00256 | .00363 | 1993.3 |
| .00266 | .00363 | 2162.7 |
| .00320 | .00434 | 2305.3 |
| .00345 | .00458 | 2568.9 |
| .00355 | .00543 | 2735.4 |
| .00400 | .00594 | 2972.2 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| .00016 | .00029 | .2 |
| .00022 | .00039 | .3 |
| .00013 | .00055 | .4 |
| .00061 | .00135 | .7 |
| .00063 | .00149 | .9 |
| .00104 | .00156 | 1.0 |
| .00125 | .00193 | 1.2 |
| .00176 | .00208 | 1.4 |
| .00224 | .00241 | 1.7 |
| .00248 | .00315 | 2.0 |
| .00252 | .00360 | 2.3 |
| .02237 | .02377 | 18.0 |
| .02360 | .02436 | 20.3 |
| .02434 | .02524 | 21.3 |
| .02455 | .02579 | 22.3 |
| .02557 | .02636 | 23.3 |
| .02619 | .02754 | 24.3 |
| .02678 | .02760 | 25.3 |
| .02720 | .02845 | 26.3 |
| .02796 | .02795 | 27.3 |
| STRESS - 103.4 MN/M2 (15.0 KSI) | | |
| -.00018 | .00026 | .2 |
| -.00005 | .00026 | .3 |
| .00008 | .00077 | .4 |
| .00068 | .00093 | .7 |
| .00086 | .00110 | .9 |
| .00119 | .00126 | 1.2 |
| .00162 | .00195 | 2.1 |
| .00219 | .00191 | 2.3 |
| .00231 | .00229 | 2.5 |
| .00808 | .00874 | 19.0 |
| .00834 | .00836 | 20.4 |

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 103.4 MN/M2 (15.0 KSI) | | |
| .00850 | .01201 | 22.4 |
| .00906 | .01158 | 24.2 |
| .00938 | .01126 | 26.2 |
| .02041 | .02069 | 91.1 |
| .02050 | .02409 | 95.1 |
| .02111 | .02398 | 117.4 |
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| -.00004 | -.00001 | .2 |
| .00042 | .00072 | .3 |
| .00042 | .00072 | .4 |
| .00042 | .00071 | .6 |
| .00102 | .00071 | 1.0 |
| .00140 | .00075 | 1.5 |
| .00105 | .00087 | 2.1 |
| .00129 | .00243 | 18.4 |
| .00138 | .00234 | 19.5 |
| .00159 | .00244 | 20.5 |
| .00259 | .00259 | 21.1 |
| .00268 | .00292 | 23.2 |
| .00192 | .00280 | 24.0 |
| .00160 | .00258 | 24.9 |
| .00200 | .00263 | 25.9 |
| .00279 | .00423 | 46.0 |
| .00276 | .00393 | 48.1 |
| .00269 | .00381 | 50.0 |
| .00433 | .00554 | 113.3 |
| .00435 | .00580 | 119.0 |
| .00473 | .00598 | 139.5 |
| .00502 | .00619 | 141.9 |
| .00520 | .00620 | 144.1 |
| .00546 | .00662 | 160.6 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 51.7 MN/M2 ( 7.5 KSI) | | |
| .00004 | -.00006 | .2 |
| .00013 | .00001 | .3 |
| .00028 | .00010 | .6 |
| .00028 | .00014 | .8 |
| .00042 | .00010 | 1.7 |
| .00047 | .00017 | 2.7 |
| .00049 | .00017 | 3.3 |
| .00210 | .00086 | 19.0 |
| .00238 | .00106 | 22.4 |
| .00259 | .00088 | 27.2 |
| .00285 | .00151 | 43.1 |
| .00307 | .00144 | 47.1 |
| .00349 | .00151 | 50.1 |
| .00439 | .00248 | 67.1 |
| .00464 | .00194 | 70.9 |
| .00475 | .00213 | 75.2 |
| .00465 | .00251 | 90.1 |
| .00488 | .00253 | 94.6 |
| .00475 | .00269 | 99.2 |
| .00450 | .00409 | 166.7 |
| .00587 | .00330 | 170.4 |
| .00640 | .00376 | 174.5 |
| .00676 | .00437 | 190.7 |
| .00711 | .00442 | 195.5 |
| .00712 | .00431 | 198.2 |
| .00698 | .00455 | 214.4 |
| .00701 | .00455 | 218.1 |
| .00813 | .00538 | 262.2 |
| .00864 | .00610 | 266.5 |
| .00858 | .00595 | 270.5 |
| .00920 | .00600 | 333.3 |
| .01088 | .00610 | 339.2 |
| .01076 | .00608 | 342.4 |

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 34.5 MN/M2 ( 5.0 KSI) | | |
| .00018 | -.00004 | .3 |
| .00032 | -.00013 | .4 |
| .00045 | -.00012 | .5 |
| .00052 | .00005 | .6 |
| .00065 | .00021 | .7 |
| .00068 | .00008 | .9 |
| .00068 | -.00001 | 1.1 |
| .00076 | -.00012 | 2.0 |
| .00085 | .00032 | 4.6 |
| .00057 | .00013 | 5.2 |
| .00108 | .00023 | 20.1 |
| .00072 | .00010 | 25.3 |
| .00072 | .00014 | 28.2 |
| .00140 | .00014 | 90.4 |
| .00101 | .00017 | 94.7 |
| .00157 | .00041 | 98.0 |
| .00179 | .00066 | 114.4 |
| .00114 | .00070 | 118.0 |
| .00141 | .00068 | 122.7 |
| .00141 | .00074 | 138.7 |
| .00138 | .00073 | 142.5 |
| .00164 | .00058 | 146.7 |
| .00192 | .00066 | 162.4 |
| .00164 | .00090 | 170.8 |
| .00194 | .00097 | 188.1 |
| .00162 | .00074 | 195.8 |
| .00160 | .00077 | 260.6 |
| .00183 | .00103 | 268.4 |
| .00237 | .00137 | 284.5 |
| .00248 | .00136 | 290.9 |
| .00259 | .00131 | 308.2 |
| .00275 | .00176 | 356.2 |
| .00298 | .00192 | 364.4 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 34.5 MN/M2 ( 5.0 KSI) | | |
| .00237 | .00174 | 428.1 |
| .00289 | .00168 | 436.3 |
| .00329 | .00080 | 452.2 |
| .00349 | .00222 | 460.2 |
| .00368 | .00215 | 476.4 |
| .00357 | .00105 | 484.7 |
| .00456 | .00241 | 500.5 |
| .00386 | .00264 | 507.6 |
| .00374 | .00269 | 524.5 |
| .00391 | .00240 | 532.3 |
| .00417 | .00248 | 548.4 |
| .00406 | .00240 | 552.6 |
| .00300 | .00138 | 572.4 |
| .00210 | .00080 | 580.4 |
| .00212 | .00093 | 596.9 |
| .00215 | .00079 | 604.6 |
| .00192 | .00095 | 620.5 |
| .00256 | .00143 | 628.7 |
| .00253 | .00168 | 644.5 |
| .00232 | .00173 | 652.1 |
| .00239 | .00183 | 717.0 |
| .00236 | .00196 | 724.5 |
| .00285 | .00202 | 740.8 |
| .00284 | .00120 | 748.6 |
| .00304 | .00155 | 763.0 |
| .00286 | .00157 | 772.7 |
| .00303 | .00150 | 788.6 |
| .00305 | .00142 | 796.6 |
| .00323 | .00159 | 815.1 |
| .00346 | .00183 | 885.1 |
| .00309 | .00198 | 892.7 |
| .00362 | .00209 | 908.6 |
| .00371 | .00205 | 916.5 |

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 34.5 MN/M2 ( 5.0 KSI) | | |
| .00359 | .00194 | 933.1 |
| .00365 | .00198 | 940.7 |
| .00352 | .00211 | 956.6 |
| .00339 | .00192 | 963.9 |
| .00400 | .00249 | 980.9 |
| .00457 | .00257 | 1052.7 |
| .00407 | .00200 | 1076.8 |
| .00380 | .00170 | 1100.8 |
| .00385 | .00230 | 1124.6 |
| .00439 | .00237 | 1148.9 |
| .00429 | .00247 | 1220.6 |
| .00437 | .00230 | 1244.8 |
| .00379 | .00181 | 1268.9 |
| .00403 | .00221 | 1292.6 |
| .00454 | .00244 | 1316.7 |
| .00371 | .00231 | 1388.8 |
| .00397 | .00268 | 1412.6 |
| .00399 | .00216 | 1436.7 |
| .00406 | .00219 | 1460.9 |
| .00417 | .00237 | 1484.8 |
| .00388 | .00241 | 1557.5 |
| .00406 | .00227 | 1582.0 |
| .00421 | .00239 | 1606.0 |
| .00394 | .00225 | 1630.7 |
| .00460 | .00278 | 1654.6 |
| .00500 | .00279 | 1749.2 |
| .00485 | .00275 | 1772.2 |
| .00476 | .00289 | 1796.4 |
| .00466 | .00281 | 1820.8 |
| .00528 | .00315 | 1895.1 |
| .00501 | .00290 | 1919.1 |
| .00513 | .00298 | 1940.7 |
| .00511 | .00349 | 1965.5 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 625
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN | | TIME: |
|---|---|---|
| TOP SPECIMEN | BOTTOM SPECIMEN | HOURS |
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00529 | .00319 | 1992.9 |
| .00559 | .00355 | 2061.7 |
| .00590 | .00350 | 2088.3 |
| .00573 | .00378 | 2110.0 |
| .00578 | .00377 | 2137.6 |
| .00570 | .00373 | 2161.8 |
| .00606 | .00416 | 2228.7 |
| .00652 | .00443 | 2258.4 |
| .00643 | .00440 | 2282.5 |
| .00664 | .00455 | 2328.2 |
| .00749 | .00518 | 2397.9 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 275.8 MN/M2 (40.0 KSI) | | |
| .00017 | .00008 | .3 |
| .00042 | .00038 | .4 |
| .00065 | .00032 | .5 |
| .00056 | .00014 | .6 |
| .00056 | .00009 | .8 |
| .00051 | .00020 | 1.0 |
| .00053 | -.00007 | 1.3 |
| .00062 | 0.00000 | 1.8 |
| .00248 | .00164 | 2.4 |
| .00224 | .00196 | 2.8 |
| .00207 | .00460 | 18.6 |
| .00177 | .00500 | 19.8 |
| .00129 | .00890 | 21.1 |
| STRESS - 206.8 MN/M2 (30.0 KSI) | | |
| .00008 | .00002 | .3 |
| .00012 | .00007 | .4 |
| .00013 | .00010 | .7 |
| .00049 | .00037 | 1.7 |
| .00058 | .00044 | 2.5 |
| .00159 | .00152 | 19.1 |
| .00130 | .00128 | 21.7 |
| .00158 | .00180 | 26.7 |
| .00476 | .01056 | 90.5 |
| .00469 | .01061 | 94.8 |
| .00489 | .01275 | 98.6 |
| .00638 | .01972 | 115.1 |
| .00656 | .02192 | 119.7 |

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| .00016 | -.00064 | .4 |
| -.00072 | .00014 | 1.4 |
| -.00060 | .00014 | 2.7 |
| .00075 | .00072 | 18.8 |
| -.00019 | .00083 | 22.8 |
| -.00042 | .00040 | 26.9 |
| -.00050 | -.00012 | 43.0 |
| -.00089 | .00177 | 46.1 |
| -.00105 | .00155 | 49.8 |
| .00114 | .00165 | 66.9 |
| -.00014 | .00139 | 70.6 |
| .00074 | .00100 | 74.6 |
| .00097 | .00434 | 139.0 |
| .00081 | .00436 | 142.8 |
| .00245 | .00421 | 163.0 |
| .00268 | .00444 | 165.3 |
| .00305 | .00426 | 169.4 |
| .00362 | .00520 | 187.0 |
| .00388 | .00548 | 190.9 |
| .00364 | .00547 | 194.9 |
| .00432 | .00578 | 211.0 |
| .00404 | .00465 | 215.7 |
| .00431 | .00454 | 218.6 |
| .00472 | .00978 | 235.0 |
| .00504 | .01099 | 239.8 |
| .00525 | .01099 | 242.4 |
| .00798 | .02090 | 307.0 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| -.00005 | -.00028 | .3 |
| -.00042 | -.00061 | .4 |
| -.00138 | -.00170 | 2.8 |
| -.00005 | .00018 | 18.9 |
| .00009 | .00004 | 22.8 |
| -.00006 | .00055 | 26.9 |
| .00005 | -.00024 | 43.0 |
| .00016 | .00052 | 47.0 |
| .00035 | .00073 | 51.2 |
| .00071 | .00083 | 115.0 |
| .00021 | .00065 | 120.2 |
| .00051 | .00072 | 122.6 |
| .00022 | .00120 | 138.9 |
| .00056 | .00124 | 142.1 |
| .00028 | .00134 | 146.7 |
| .00066 | .00139 | 163.0 |
| .00026 | .00198 | 167.9 |
| .00056 | .00211 | 186.9 |
| .00051 | .00236 | 190.5 |
| .00048 | .00217 | 194.2 |
| .00075 | .00228 | 210.9 |
| .00109 | .00233 | 214.6 |
| .00116 | .00223 | 218.4 |
| .00172 | .00314 | 282.9 |
| .00163 | .00304 | 286.6 |
| .00163 | .00329 | 290.9 |
| .00172 | .00361 | 307.1 |
| .00179 | .00552 | 310.5 |
| .00162 | .00408 | 314.7 |
| .00188 | .00407 | 330.8 |
| .00195 | .00419 | 335.9 |
| .00210 | .00439 | 354.9 |
| .00240 | .00474 | 362.9 |

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00238 | .00496 | 378.8 |
| .00276 | .00518 | 384.7 |
| .00253 | .00503 | 387.5 |
| .00308 | .00617 | 467.6 |
| .00302 | .00630 | 475.7 |
| .00317 | .00583 | 491.4 |
| .00342 | .00675 | 499.6 |
| .00372 | .00646 | 515.4 |
| .00392 | .00649 | 523.5 |
| .00381 | .00718 | 539.7 |
| .00416 | .00720 | 547.7 |
| .00414 | .00787 | 563.4 |
| .00436 | .00877 | 571.4 |
| .00529 | .00955 | 635.7 |
| .00550 | .00955 | 645.0 |
| STRESS - 51.7 MN/M2 ( 7.5 KSI) | | |
| .00010 | .00030 | .6 |
| .00073 | -.00079 | 1.3 |
| .00055 | .00015 | 17.5 |
| .00044 | .00004 | 24.9 |
| .00044 | .00024 | 42.9 |
| .00097 | .00039 | 115.4 |
| .00407 | .00035 | 139.4 |
| .00095 | .00095 | 161.7 |
| .00105 | .00096 | 187.1 |
| .00115 | .00147 | 225.5 |
| .00217 | .00193 | 294.8 |
| .00176 | .00227 | 320.9 |
| .00210 | .00230 | 342.4 |
| .00203 | .00275 | 370.1 |
| .00229 | .00295 | 394.8 |
| .00274 | .00345 | 461.3 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00329 | .00374 | 491.3 |
| .00329 | .00386 | 515.0 |
| .00361 | .00409 | 561.3 |
| .00399 | .00443 | 630.4 |
| .00413 | .00502 | 653.6 |
| .00414 | .00511 | 679.3 |
| .00455 | .00505 | 706.9 |
| .00446 | .00519 | 726.6 |
| .00490 | .00577 | 802.3 |
| .00505 | .00547 | 825.0 |
| .00519 | .00591 | 849.6 |
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00040 | .00035 | .5 |
| .00075 | .00067 | 2.1 |
| .00099 | .00072 | 27.0 |
| .00139 | .00102 | 52.8 |
| .00139 | .00086 | 125.0 |
| .00205 | .00077 | 150.6 |
| .00159 | .00052 | 197.2 |
| .00221 | .00037 | 221.3 |
| .00235 | .00041 | 318.6 |
| .00240 | .00023 | 366.3 |
| .00283 | .00055 | 389.6 |
| .00278 | .00102 | 482.6 |
| .00283 | .00102 | 511.5 |
| .00323 | .00107 | 535.5 |
| .00345 | .00112 | 555.2 |
| .00353 | .00165 | 629.9 |
| .00363 | .00162 | 654.6 |
| .00387 | .00179 | 678.8 |
| .00374 | .00179 | 725.9 |
| .00400 | .00190 | 798.1 |

MATERIAL - INCONEL 718
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00429 | .00212 | 823.1 |
| .00458 | .00207 | 869.9 |
| .00481 | .00217 | 893.0 |
| .00436 | .00224 | 965.5 |
| .00489 | .00247 | 1014.3 |
| .00493 | .00253 | 1063.2 |
| .00521 | .00247 | 1133.9 |
| .00535 | .00265 | 1179.3 |
| .00635 | .00280 | 1224.3 |
| .00493 | .00295 | 1373.6 |
| .00503 | .00312 | 1541.3 |
| .00560 | .00327 | 1637.2 |
| .00573 | .00347 | 1685.4 |
| .00593 | .00367 | 1805.4 |
| .00610 | .00383 | 1853.2 |
| .00653 | .00407 | 1974.9 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 137.9 MN/M2 (20.0 KSI) | | |
| .00017 | .00006 | .4 |
| .00034 | .00023 | .5 |
| .00038 | .00042 | .7 |
| .00087 | .00089 | 1.1 |
| .00148 | .00102 | 1.8 |
| .00182 | .00129 | 2.2 |
| .00221 | .00140 | 2.8 |
| .00995 | .00881 | 18.9 |
| .01118 | .00998 | 19.7 |
| .01168 | .00983 | 20.6 |
| .01186 | .01011 | 21.5 |
| .01225 | .01017 | 22.6 |
| .01291 | .01062 | 23.6 |
| STRESS - 103.4 MN/M2 (15.0 KSI) | | |
| .00018 | .00014 | .1 |
| .00023 | .00006 | .2 |
| .00039 | .00017 | .4 |
| .00044 | .00022 | .6 |
| .00049 | .00024 | .8 |
| .00075 | .00043 | 1.7 |
| .00115 | .00084 | 3.1 |
| .00336 | .00258 | 19.0 |
| .00430 | .00298 | 23.1 |
| .00473 | .00347 | 26.8 |
| .00705 | .00485 | 43.0 |
| .00739 | .00498 | 46.7 |
| .00789 | .00514 | 51.0 |
| .01020 | .00655 | 67.0 |
| .01031 | .00661 | 70.1 |
| .01043 | .00722 | 74.9 |
| .01724 | .01160 | 139.0 |
| .01646 | .01163 | 142.9 |

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 103.4 MN/M2 (15.0 KSI) | | |
| .01785 | .01173 | 146.9 |
| .01904 | .01311 | 163.0 |
| .01929 | .01353 | 167.0 |
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00048 | .00040 | .3 |
| .00056 | .00093 | .5 |
| .00075 | .00093 | 1.5 |
| .00082 | .00124 | 2.2 |
| .00182 | .00180 | 18.7 |
| .00185 | .00199 | 21.8 |
| .00187 | .00180 | 26.5 |
| .00375 | .00343 | 91.0 |
| .00252 | .00345 | 95.0 |
| .00281 | .00178 | 115.0 |
| .00253 | .00176 | 118.8 |
| .00242 | .00177 | 122.6 |
| .00282 | .00199 | 139.0 |
| .00272 | .00193 | 142.5 |
| .00281 | .00209 | 146.7 |
| .00337 | .00245 | 163.0 |
| .00387 | .00276 | 168.1 |
| .00377 | .00276 | 171.9 |
| .00440 | .00303 | 187.0 |
| .00401 | .00310 | 192.0 |
| .00440 | .00307 | 194.9 |
| .00506 | .00367 | 259.0 |
| .00480 | .00359 | 262.7 |
| .00489 | .00356 | 266.5 |
| .00515 | .00401 | 283.0 |
| .00492 | .00404 | 286.4 |
| .00544 | .00437 | 290.7 |
| .00552 | .00458 | 307.0 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00566 | .00450 | 310.6 |
| .00570 | .00457 | 314.7 |
| .00615 | .00475 | 331.0 |
| .00602 | .00460 | 335.6 |
| .00622 | .00490 | 339.4 |
| .00628 | .00473 | 355.0 |
| .00686 | .00497 | 358.4 |
| .00673 | .00510 | 363.1 |
| .00703 | .00555 | 427.0 |
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00054 | .00056 | 1.4 |
| .00070 | .00052 | 2.9 |
| .00171 | .00107 | 18.8 |
| .00192 | .00165 | 22.8 |
| .00216 | .00175 | 27.0 |
| .00274 | .00215 | 42.8 |
| .00256 | .00224 | 46.5 |
| .00237 | .00231 | 50.6 |
| .00312 | .00233 | 66.9 |
| .00310 | .00258 | 70.6 |
| .00292 | .00291 | 74.7 |
| .00335 | .00264 | 139.6 |
| .00351 | .00300 | 146.2 |
| .00318 | .00266 | 164.1 |
| .00348 | .00262 | 188.0 |
| .00390 | .00282 | 212.3 |
| .00397 | .00305 | 236.6 |
| .00432 | .00328 | 331.6 |
| .00430 | .00344 | 354.6 |
| .00472 | .00359 | 378.7 |
| .00517 | .00389 | 403.1 |
| .00515 | .00365 | 477.4 |

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00518 | .00378 | 501.4 |
| .00547 | .00392 | 525.0 |
| .00541 | .00410 | 550.0 |
| .00482 | .00384 | 577.6 |
| .00585 | .00402 | 646.5 |
| .00616 | .00397 | 673.0 |
| .00597 | .00400 | 694.6 |
| .00656 | .00411 | 722.3 |
| .00619 | .00414 | 746.5 |
| .00655 | .00382 | 813.4 |
| .00669 | .00385 | 843.1 |
| .00676 | .00386 | 864.2 |
| .00653 | .00384 | 913.0 |
| .00675 | .00384 | 982.5 |
| .00649 | .00386 | 1005.3 |
| .00667 | .00406 | 1031.4 |
| .00696 | .00383 | 1057.5 |
| .00715 | .00420 | 1077.9 |
| .00735 | .00453 | 1154.0 |
| .00706 | .00458 | 1177.2 |
| .00718 | .00421 | 1201.4 |
| .00710 | .00422 | 1226.0 |
| .00721 | .00454 | 1245.8 |
| .00728 | .00464 | 1321.1 |
| .00709 | .00496 | 1347.7 |
| .00695 | .00420 | 1367.7 |
| .00749 | .00460 | 1394.5 |
| .00749 | .00460 | 1413.5 |
| .00723 | .00480 | 1486.4 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

STRESS - 34.5 MN/M2 ( 5.0 KSI)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| -.00033 | .00016 | .4 |
| .00159 | .00100 | 23.9 |
| .00194 | .00143 | 96.0 |
| .00208 | .00150 | 120.9 |
| .00185 | .00136 | 168.2 |
| .00205 | .00157 | 191.9 |
| .00206 | .00199 | 289.6 |
| .00212 | .00199 | 337.2 |
| .00219 | .00197 | 360.7 |
| .00225 | .00197 | 453.1 |
| .00228 | .00199 | 482.4 |
| .00233 | .00224 | 506.3 |
| .00226 | .00232 | 525.7 |
| .00249 | .00255 | 600.9 |
| .00261 | .00213 | 625.1 |
| .00274 | .00211 | 649.7 |
| .00214 | .00258 | 696.1 |
| .00250 | .00220 | 769.1 |
| .00267 | .00224 | 794.0 |
| .00272 | .00211 | 840.5 |
| .00272 | .00211 | 863.9 |
| .00260 | .00217 | 936.1 |
| .00254 | .00223 | 985.2 |
| .00239 | .00241 | 1033.9 |
| .00247 | .00231 | 1104.9 |
| .00234 | .00211 | 1149.9 |
| .00234 | .00211 | 1195.3 |
| .00244 | .00211 | 1344.9 |
| .00244 | .00241 | 1512.2 |
| .00338 | .00321 | 1607.8 |
| .00356 | .00314 | 1656.3 |
| .00410 | .00379 | 1776.0 |
| .00374 | .00341 | 1824.4 |

MATERIAL - HAYNES 25
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

STRESS - 34.5 MN/M2 ( 5.0 KSI)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| .00378 | .00351 | 1945.4 |
| .00394 | .00351 | 2111.9 |
| .00380 | .00343 | 2205.1 |
| .00389 | .00361 | 2304.0 |
| .00376 | .00341 | 2447.7 |
| .00420 | .00361 | 2803.2 |
| .00422 | .00387 | 3048.9 |
| .00422 | .00387 | 3217.7 |
| .00404 | .00387 | 3330.9 |
| .00414 | .00341 | 3480.6 |
| .00456 | .00391 | 3838.0 |
| .00484 | .00391 | 4204.9 |
| .00496 | .00496 | 4416.6 |
| .00476 | .00455 | 4685.2 |
| .00559 | .00503 | 5115.7 |
| .00689 | .00547 | 5231.8 |
| .00692 | .00522 | 5278.7 |
| .00673 | .00577 | 5352.5 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 103.4 MN/M2 (15.0 KSI) | | |
| .00027 | 0.00000 | .3 |
| .00042 | .00020 | .4 |
| .00040 | .00044 | .9 |
| .00059 | .00062 | 2.0 |
| .00098 | .00068 | 2.6 |
| .00269 | .00232 | 18.7 |
| .00320 | .00248 | 22.5 |
| .00343 | .00283 | 25.7 |
| .00602 | .00434 | 42.9 |
| .00663 | .00454 | 50.3 |
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00002 | .00004 | .3 |
| .00014 | .00018 | .4 |
| .00014 | .00026 | .5 |
| .00022 | .00040 | 1.0 |
| .00052 | .00050 | 2.6 |
| .00090 | .00120 | 18.9 |
| .00144 | .00125 | 26.6 |
| .00168 | .00172 | 42.7 |
| .00190 | .00181 | 50.7 |
| .00210 | .00200 | 74.7 |
| .00225 | .00247 | 98.1 |
| .00280 | .00247 | 164.5 |
| .00325 | .00284 | 193.9 |
| .00310 | .00290 | 218.2 |
| .00349 | .00313 | 265.9 |
| .00376 | .00353 | 338.4 |
| .00393 | .00375 | 385.4 |
| .00459 | .00433 | 600.3 |
| .00524 | .00467 | 743.4 |
| .00544 | .00502 | 883.3 |
| .00582 | .00520 | 1051.4 |

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - 68.9 MN/M2 (10.0 KSI) | | |
| .00590 | .00574 | 1198.9 |
| STRESS - 51.7 MN/M2 ( 7.5 KSI) | | |
| 0.00000 | 0.00000 | .2 |
| .00019 | .00006 | .9 |
| .00021 | .00013 | 1.7 |
| .00054 | .00078 | 17.9 |
| .00074 | .00064 | 25.7 |
| .00098 | .00086 | 41.9 |
| .00124 | .00114 | 67.2 |
| .00140 | .00166 | 163.8 |
| .00178 | .00214 | 214.0 |
| .00214 | .00268 | 262.7 |
| .00227 | .00272 | 330.6 |
| .00284 | .00276 | 379.4 |
| .00228 | .00250 | 524.1 |
| .00288 | .00310 | 575.6 |
| .00323 | .00340 | 695.9 |
| .00331 | .00334 | 838.4 |
| .00336 | .00335 | 911.0 |
| .00310 | .00348 | 1031.6 |
| .00340 | .00374 | 1171.0 |
| .00381 | .00414 | 1341.9 |
| .00413 | .00446 | 1530.5 |
| .00413 | .00453 | 1701.9 |
| .00472 | .00504 | 1895.5 |
| .00494 | .00553 | 2040.0 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 34.5 MN/M2 | ( 5.0 KSI) |
| .00032 | | .6 |
| .00054 | | .8 |
| .00014 | | 1.3 |
| .00039 | | 2.4 |
| .00047 | | 19.3 |
| .00086 | | 43.1 |
| .00116 | | 67.3 |
| .00106 | | 145.7 |
| .00156 | | 212.3 |
| .00160 | | 313.0 |
| .00186 | | 505.2 |
| .00182 | | 648.9 |
| .00222 | | 815.9 |
| .00291 | | 986.8 |
| .00298 | | 1155.4 |
| .00272 | | 1323.1 |
| .00312 | | 1515.8 |
| .00345 | | 1707.4 |
| .00342 | | 1922.4 |
| .00398 | | 2374.2 |
| .00400 | | 2521.8 |
| .00410 | | 2690.6 |
| .00397 | | 2833.4 |
| .00448 | | 3097.1 |
| .00482 | | 3264.0 |
| .00462 | | 3500.5 |

MATERIAL - HAYNES 188
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 | (15.0 KSI) |
| .00043 | .00014 | .3 |
| .00056 | .00043 | .4 |
| .00076 | .00050 | .6 |
| .00097 | .00072 | 1.0 |
| .00152 | .00145 | 2.1 |
| .00450 | .00655 | 18.1 |
| .00564 | .00790 | 25.1 |
| STRESS - | 68.9 MN/M2 | (10.0 KSI) |
| .00010 | .00020 | .3 |
| .00014 | .00020 | .5 |
| .00022 | .00040 | .8 |
| .00060 | .00095 | 2.5 |
| .00178 | .00300 | 23.3 |
| .00322 | .00398 | 50.1 |
| .00347 | .00582 | 71.4 |
| .00489 | .00776 | 139.2 |
| .00535 | .00794 | 146.3 |
| STRESS - | 51.7 MN/M2 | ( 7.5 KSI) |
| .00022 | .00077 | .3 |
| .00029 | .00089 | .4 |
| 0.00000 | .00034 | 1.0 |
| .00028 | .00114 | 1.8 |
| .00082 | .00143 | 2.9 |
| .00088 | .00180 | 19.7 |
| .00110 | .00248 | 27.0 |
| .00110 | .00260 | 45.8 |
| .00148 | .00306 | 50.9 |
| .00156 | .00360 | 72.0 |
| .00226 | .00440 | 163.4 |
| .00229 | .00454 | 241.7 |
| .00275 | .00534 | 432.4 |
| .00394 | .00628 | 602.3 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00319 | .00583 | .1 |
| .00596 | .00873 | .2 |
| .00827 | .01560 | .3 |
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00010 | | .2 |
| .00077 | | .3 |
| .00114 | | .4 |
| .00139 | | .5 |
| .00173 | | .6 |
| .00227 | | .8 |
| .00311 | | 1.0 |
| .00424 | | 1.3 |
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00035 | .00035 | .2 |
| .00055 | .00089 | .3 |
| .00060 | .00097 | .5 |
| .00140 | .00208 | 1.5 |
| .00197 | .00325 | 3.0 |
| .01653 | .04134 | 19.3 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| -.00020 | .00030 | .4 |
| .00016 | .00030 | .7 |
| .00070 | .00123 | .8 |
| .00088 | .00137 | 1.0 |
| .00082 | .00157 | 1.2 |
| .00080 | .00130 | 1.7 |
| .00080 | .00134 | 2.3 |
| .00094 | .00159 | 3.0 |
| .00176 | .00241 | 19.0 |
| .00257 | .00337 | 23.8 |

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00262 | .00365 | 27.0 |
| .00306 | .00457 | 43.1 |
| .00337 | .00473 | 46.0 |
| .00361 | .00535 | 50.2 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00111 | .00107 | .4 |
| .00192 | .00336 | .5 |
| .00271 | .00400 | .6 |
| .00536 | .00880 | .9 |
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| -.00057 | -.00014 | .3 |
| .00045 | -.00007 | .5 |
| .00086 | .00086 | 1.4 |
| .00142 | .00077 | 3.1 |
| .00518 | .00063 | 20.2 |
| .00531 | .00066 | 26.7 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00023 | .00002 | .3 |
| .00050 | .00007 | .4 |
| .00058 | .00023 | .5 |
| .00066 | .00029 | .8 |
| .00090 | .00067 | 2.2 |
| .00256 | .00340 | 19.2 |
| .00330 | .00498 | 26.7 |
| .00482 | .00785 | 43.0 |

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN: TOP SPECIMEN | STRAIN: BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00004 | -.00012 | .3 |
| .00003 | .00012 | .5 |
| .00026 | .00015 | .6 |
| .00029 | .00052 | 1.6 |
| .00012 | .00066 | 4.6 |
| .00163 | .00306 | 20.5 |
| .00262 | .00431 | 28.3 |
| .00318 | .00567 | 44.6 |
| .00323 | .00546 | 52.0 |
| .00594 | .00948 | 93.6 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN, TOP SPECIMEN | STRAIN, BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 55.2 MN/M2 ( 8.0 KSI) | |
| .00013 | -.00003 | .3 |
| .00018 | .00013 | .4 |
| .00036 | .00015 | .5 |
| .00045 | .00016 | .7 |
| .00070 | .00026 | 1.4 |
| .00086 | .00099 | 3.4 |
| .00116 | .00132 | 4.5 |
| .00220 | .00315 | 20.4 |
| .00210 | .00340 | 28.4 |
| .00316 | .00474 | 47.3 |
| .00433 | .00648 | 70.3 |
| STRESS - | 48.3 MN/M2 ( 7.0 KSI) | |
| .00008 | .00010 | .3 |
| .00002 | .00069 | .4 |
| .00002 | .00070 | .5 |
| .00013 | .00070 | .8 |
| .00034 | .00090 | 1.6 |
| .00046 | .00084 | 2.9 |
| .00047 | .00083 | 4.4 |
| .00161 | .00186 | 20.6 |
| .00179 | .00207 | 28.5 |
| .00200 | .00261 | 44.9 |
| .00243 | .00315 | 76.0 |
| .00340 | .00455 | 165.0 |
| .00437 | .00600 | 196.3 |
| .00513 | .00700 | 244.5 |

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN, TOP SPECIMEN | STRAIN, BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 41.4 MN/M2 ( 6.0 KSI) | |
| .00024 | .00005 | .2 |
| .00029 | .00004 | .3 |
| .00020 | .00002 | .7 |
| .00060 | .00005 | 1.5 |
| .00073 | .00018 | 2.6 |
| .00070 | .00041 | 4.3 |
| .00080 | .00043 | 5.7 |
| .00060 | .00055 | 15.7 |
| .00123 | .00109 | 45.4 |
| .00206 | .00212 | 109.8 |
| .00252 | .00213 | 141.7 |
| .00232 | .00265 | 164.6 |
| .00249 | .00260 | 189.7 |
| .00257 | .00296 | 213.7 |
| .00236 | .00363 | 278.4 |
| .00374 | .00368 | 301.8 |
| .00383 | .00403 | 333.7 |
| .00350 | .00385 | 357.5 |
| .00420 | .00416 | 381.3 |
| .00442 | .00423 | 446.3 |
| .00444 | .00465 | 477.4 |
| .00449 | .00484 | 501.5 |
| .00467 | .00490 | 525.1 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 27.6 MN/M2 ( 4.0 KSI) | |
| .00024 | .00060 | .3 |
| .00052 | .00103 | .4 |
| .00080 | .00097 | .6 |
| .00080 | .00070 | 1.6 |
| .00146 | .00094 | 18.9 |
| .00305 | .00122 | 26.3 |
| .00578 | .00197 | 43.2 |
| .00576 | .00143 | 49.5 |
| STRESS - | 27.6 MN/M2 ( 4.0 KSI) | |
| .00060 | .00014 | .2 |
| .00067 | .00034 | .4 |
| .00065 | .00057 | .6 |
| .00056 | .00021 | 1.0 |
| .00080 | .00054 | 2.9 |
| .00194 | .00188 | 19.0 |
| .00284 | .00265 | 27.0 |
| .00432 | .00407 | 43.0 |
| .00574 | .00470 | 50.3 |
| STRESS - | 24.1 MN/M2 ( 3.5 KSI) | |
| .00020 | 0.00000 | .2 |
| .00016 | .00010 | .4 |
| .00018 | .00023 | .9 |
| .00030 | .00100 | 2.2 |
| .00016 | .00132 | 4.9 |
| .00085 | .00270 | 21.0 |
| .00120 | .00299 | 28.7 |
| .00182 | .00386 | 44.9 |
| .00238 | .00432 | 52.5 |
| .00597 | .00934 | 117.6 |
| STRESS - | 24.1 MN/M2 ( 3.5 KSI) | |
| .00028 | .00003 | .3 |

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 24.1 MN/M2 ( 3.5 KSI) | |
| .00043 | .00065 | .6 |
| .00052 | .00084 | 1.4 |
| .00034 | .00092 | 3.2 |
| .00033 | .00115 | 4.4 |
| .00110 | .00155 | 20.6 |
| .00116 | .00218 | 28.3 |
| .00249 | .00366 | 68.7 |
| .00316 | .00473 | 99.8 |
| .00381 | .00562 | 165.3 |
| .00412 | .00638 | 188.8 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00026 | .00017 | .2 |
| .00030 | .00043 | .4 |
| .00040 | .00030 | .6 |
| .00052 | .00052 | 1.2 |
| .00053 | .00065 | 2.1 |
| .00044 | .00078 | 4.4 |
| .00104 | .00116 | 21.2 |
| .00126 | .00150 | 28.5 |
| .00218 | .00287 | 45.9 |
| .00222 | .00346 | 53.1 |
| .00269 | .00490 | 77.1 |
| .00375 | .01153 | 165.0 |
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00009 | .00003 | .2 |
| .00008 | .00019 | .5 |
| .00055 | .00004 | 1.5 |
| .00096 | .00085 | 19.0 |
| .00139 | .00140 | 26.9 |
| .00186 | .00124 | 43.0 |
| .00201 | .00160 | 66.8 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - HAYNES 188
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 20.7 MN/M2 ( 3.0 KSI) | |
| .00345 | .00294 | 139.1 |
| .00416 | .00340 | 163.2 |
| .00452 | .00390 | 189.9 |
| .00532 | .00449 | 212.9 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 137.9 MN/M2 (20.0 KSI) | |
| .00042 | .00001 | .2 |
| .00079 | .00055 | .5 |
| .00100 | .00028 | 4.7 |
| .00302 | .00110 | 20.7 |
| .00427 | .00234 | 25.7 |
| .00371 | .00155 | 28.7 |
| .00568 | .00141 | 44.5 |
| .00427 | .00190 | 48.6 |
| .00358 | .00214 | 52.7 |
| RUPTURE | | 60.0 |
| STRESS - | 137.9 MN/M2 (20.0 KSI) | |
| 0.00000 | .00004 | .2 |
| .00028 | .00009 | .3 |
| .00048 | .00009 | .5 |
| .00048 | .00038 | .8 |
| .00070 | .00038 | 1.6 |
| .00117 | .00065 | 3.0 |
| .00340 | .00155 | 19.0 |
| .00430 | .00163 | 23.9 |
| .00450 | .00185 | 26.6 |
| .00510 | .00246 | 43.0 |
| STRESS - | 120.7 MN/M2 (17.5 KSI) | |
| 0.00000 | .00007 | .3 |
| .00024 | .00015 | .4 |
| .00024 | .00025 | .5 |
| .00026 | .00025 | .6 |
| .00026 | .00030 | .8 |
| .00030 | .00040 | 1.1 |
| .00075 | .00044 | 2.1 |
| .00075 | .00044 | 2.8 |
| .00080 | .00070 | 19.0 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 120.7 MN/M2 (17.5 KSI) | |
| .00080 | .00079 | 26.6 |
| .00100 | .00060 | 43.4 |
| .00123 | .00090 | 67.3 |
| .00134 | .00097 | 91.2 |
| .00121 | .00091 | 169.6 |
| .00151 | .00110 | 235.5 |
| .00172 | .00118 | 336.2 |
| .00204 | .00118 | 528.4 |
| .00229 | .00132 | 672.1 |
| .00278 | .00150 | 839.1 |
| .00278 | .00174 | 1010.2 |
| RUPTURE | | 1171.9 |
| STRESS - | 120.7 MN/M2 (17.5 KSI) | |
| .00011 | .00030 | .3 |
| .00027 | .00017 | .4 |
| .00032 | .00030 | .5 |
| .00030 | .00053 | 1.1 |
| .00030 | .00112 | 3.0 |
| .00035 | .00336 | 18.9 |
| .00055 | .00404 | 26.8 |
| | RUPTURE | 31.1 |
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00051 | .00035 | .3 |
| .00079 | .00043 | 3.0 |
| .00036 | .00077 | 27.0 |
| .00082 | .00083 | 99.0 |
| .00072 | .00078 | 116.0 |
| .00103 | .00174 | 189.0 |
| .00134 | .00170 | 330.0 |
| .00104 | .00161 | 428.0 |
| .00118 | .00178 | 503.0 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00098 | .00178 | 526.2 |
| .00101 | .00162 | 595.1 |
| .00118 | .00189 | 621.4 |
| .00102 | .00187 | 761.8 |
| .00109 | .00178 | 931.3 |
| .00118 | .00180 | 1006.4 |
| .00120 | .00180 | 1296.5 |
| .00112 | .00184 | 1435.3 |
| .00132 | .00204 | 1630.7 |
| .00167 | .00224 | 1846.9 |
| .00149 | .00224 | 2039.2 |
| .00159 | .00219 | 2328.4 |
| .00160 | .00225 | 2542.4 |
| .00149 | .00234 | 2874.0 |
| .00163 | .00224 | 3191.0 |
| .00141 | .00272 | 4125.7 |
| .00167 | .00264 | 5008.7 |
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00010 | .00008 | .5 |
| .00014 | .00012 | 2.1 |
| .00016 | .00017 | 20.2 |
| .00057 | .00056 | 95.6 |
| .00043 | .00050 | 188.1 |
| .00053 | .00048 | 433.4 |
| .00073 | .00064 | 600.7 |
| .00075 | .00055 | 794.2 |
| .00086 | .00077 | 1010.9 |
| .00050 | .00065 | 1200.4 |
| .00076 | .00067 | 1440.6 |
| .00082 | .00074 | 1609.5 |
| .00084 | .00094 | 2016.8 |
| .00066 | .00076 | 2449.8 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00056 | .00069 | 2952.3 |
| .00078 | .00090 | 3307.7 |
| .00089 | .00068 | 3836.3 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 137.9 MN/M2 (20.0 KSI) | |
| -.00006 | .00058 | .3 |
| .00036 | .00050 | .5 |
| .00050 | .00060 | .7 |
| .00150 | .00135 | 1.8 |
| .00192 | .00182 | 2.7 |
| .00300 | .00504 | 19.1 |
| .00309 | .00590 | 26.4 |
| STRESS - | 120.7 MN/M2 (17.5 KSI) | |
| .00008 | | .3 |
| .00018 | | .4 |
| .00043 | | .5 |
| .00053 | | .7 |
| .00042 | | 1.0 |
| .00042 | | 1.8 |
| .00042 | | 2.8 |
| .00046 | | 19.9 |
| .00052 | | 25.8 |
| .00070 | | 50.2 |
| .00117 | | 98.2 |
| .00158 | | 170.5 |
| .00214 | | 217.7 |
| .00243 | | 432.6 |
| RUPTURE | | 546.5 |

MATERIAL - TD NI-20CR
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1033 K (1400 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00004 | .00009 | .2 |
| .00012 | .00009 | .3 |
| .00023 | .00014 | .8 |
| .00018 | .00016 | 1.3 |
| .00021 | .00014 | 2.7 |
| .00020 | .00038 | 19.2 |
| .00023 | .00042 | 26.6 |
| .00028 | .00043 | 50.0 |
| .00014 | .00047 | 69.8 |
| .00020 | .00052 | 144.0 |
| .00044 | .00052 | 407.6 |
| .00016 | .00052 | 574.8 |
| .00044 | .00040 | 811.2 |
| .00028 | .00040 | 1079.9 |
| .00044 | .00040 | 1578.9 |
| STRESS - | 68.9 MN/M2 (10.0 KSI) | |
| .00013 | 0.00000 | .3 |
| .00060 | .00084 | 1.1 |
| .00040 | .00062 | 17.1 |
| .00067 | .00060 | 24.3 |
| .00084 | .00050 | 41.2 |
| .00036 | .00030 | 65.2 |
| .00031 | .00022 | 89.3 |
| .00030 | .00020 | 161.2 |
| .00043 | .00011 | 209.4 |
| .00070 | .00008 | 354.3 |
| .00050 | .00005 | 430.4 |
| .00040 | .00010 | 600.6 |
| .00037 | .00014 | 936.7 |
| .00043 | .00015 | 1402.1 |
| .00041 | .00036 | 2034.4 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 137.9 MN/M2 | (20.0 KSI) |
| | RUPTURE | 0.0 |
| STRESS - | 120.7 MN/M2 | (17.5 KSI) |
| | RUPTURE | .1 |
| STRESS - | 103.4 MN/M2 | (15.0 KSI) |
| | RUPTURE | .2 |
| STRESS - | 89.6 MN/M2 | (13.0 KSI) |
| .00076 | | .2 |
| .00096 | | .3 |
| .00110 | | .4 |
| | RUPTURE | .5 |
| STRESS - | 68.9 MN/M2 | (10.0 KSI) |
| .00020 | .00006 | .3 |
| .00024 | .00015 | .5 |
| .00030 | .00018 | 1.2 |
| .00032 | .00024 | 2.2 |
| .00034 | .00025 | 2.9 |
| .00056 | .00051 | 18.9 |
| .00065 | .00054 | 22.2 |
| .00092 | .00080 | 26.5 |
| .00090 | .00050 | 43.4 |
| .00090 | .00058 | 50.7 |
| .00110 | .00059 | 67.3 |
| RUPTURE | | 145.7 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 62.1 MN/M2 | ( 9.0 KSI) |
| 0.00000 | .00008 | .2 |
| 0.00000 | .00013 | .3 |
| .00008 | .00013 | .9 |
| .00026 | .00025 | 1.8 |
| | RUPTURE | 3.4 |
| STRESS - | 55.2 MN/M2 | ( 8.0 KSI) |
| .00007 | .00012 | .2 |
| .00007 | .00025 | .4 |
| .00013 | .00026 | .8 |
| .00013 | .00019 | 1.6 |
| .00011 | .00022 | 2.2 |
| .00021 | .00037 | 18.5 |
| .00015 | .00050 | 25.9 |
| .00025 | .00046 | 90.7 |
| .00032 | .00064 | 114.3 |
| .00029 | .00084 | 138.3 |
| .00026 | .00082 | 163.4 |
| .00021 | .00081 | 260.3 |
| .00013 | .00053 | 310.2 |
| .00023 | .00086 | 359.2 |
| .00009 | .00081 | 426.9 |
| .00007 | .00088 | 475.8 |
| .00009 | .00082 | 620.3 |
| .00076 | .00085 | 672.0 |
| .00139 | .00147 | 792.1 |
| .00370 | .00065 | 934.8 |
| .00494 | .00098 | 1007.4 |
| .00795 | .00081 | 1127.8 |
| RUPTURE | | 1149.6 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 51.7 MN/M2 ( 7.5 KSI) | |
| .00002 | .00012 | .3 |
| .00002 | .00012 | .7 |
| .00002 | .00015 | 1.3 |
| .00005 | .00012 | 2.8 |
| 0.00000 | .00035 | 19.7 |
| 0.00000 | .00037 | 26.7 |
| 0.00000 | .00077 | 43.9 |
| 0.00000 | .00072 | 50.9 |
| .00013 | .00085 | 73.8 |
| .00043 | .00057 | 144.2 |
| .00043 | .00081 | 187.2 |
| .00013 | .00111 | 336.8 |
| .00031 | .00111 | 385.8 |
| .00019 | .00129 | 524.1 |
| .00055 | .00094 | 571.1 |
| .00028 | .00117 | 694.1 |
| .00028 | .00125 | 818.2 |
| .00019 | .00121 | 1010.2 |
| .00012 | .00143 | 1061.1 |
| .00031 | .00135 | 1204.3 |
| .00012 | .00130 | 1272.9 |
| .00033 | .00159 | 1420.1 |
| .00023 | .00137 | 1541.3 |
| .00027 | .00127 | 1775.4 |
| .00113 | .00155 | 1902.2 |
| .00217 | .00140 | 1972.6 |
| | RUPTURE | 2087.4 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00006 | | .2 |
| .00006 | | .3 |
| .00008 | | .6 |
| .00005 | | 1.5 |
| .00010 | | 2.9 |
| .00028 | | 19.0 |
| .00030 | | 22.8 |
| .00031 | | 26.9 |
| .00031 | | 44.0 |
| .00031 | | 120.5 |
| .00026 | | 144.3 |
| .00014 | | 170.6 |
| .00034 | | 288.2 |
| .00034 | | 331.1 |
| .00021 | | 480.6 |
| .00030 | | 529.6 |
| .00018 | | 668.0 |
| .00018 | | 715.0 |
| .00015 | | 838.0 |
| .00015 | | 962.2 |
| .00050 | | 1154.2 |
| .00028 | | 1205.1 |
| .00029 | | 1348.3 |
| .00034 | | 1416.8 |
| .00020 | | 1564.1 |
| .00037 | | 1685.3 |
| .00052 | | 1919.5 |
| .00043 | | 2045.3 |
| .00019 | | 2116.5 |
| .00042 | | 2231.9 |
| .00040 | | 2279.5 |
| .00039 | | 2352.7 |
| .00047 | | 2524.8 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00048 | | 2615.2 |
| .00043 | | 2660.0 |
| STRESS - | 34.5 MN/M2 ( 5.0 KSI) | |
| .00002 | 0.00000 | .2 |
| .00018 | .00014 | .3 |
| .00017 | 0.00000 | .5 |
| .00017 | 0.00000 | .8 |
| .00037 | .00001 | 2.2 |
| .00064 | .00027 | 19.0 |
| .00051 | .00008 | 26.5 |
| .00056 | .00013 | 43.2 |
| .00061 | .00024 | 51.0 |
| .00067 | .00005 | 121.9 |
| .00067 | .00005 | 187.7 |
| .00061 | .00002 | 288.6 |
| .00064 | .00012 | 481.0 |
| .00050 | .00006 | 624.4 |
| .00054 | .00008 | 961.9 |
| .00050 | .00006 | 1491.3 |

MATERIAL - TD NI-20CR
THICKNESS - .254 MM( .010 IN.)
PRESSURE - 1.1 KN/M2 ( 8 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00020 | .00032 | .2 |
| .00038 | .00068 | .3 |
| .00060 | .00088 | .4 |
| .00080 | .00140 | .7 |
| .00143 | .00169 | 1.1 |
| .00276 | .00390 | 2.3 |
| | RUPTURE | 3.3 |
| STRESS - | 63.9 MN/M2 (10.0 KSI) | |
| .00025 | .00023 | .2 |
| .00025 | .00020 | .3 |
| .00023 | .00015 | .5 |
| .00014 | .00030 | 1.2 |
| .00057 | .00055 | 1.6 |
| .00045 | .00050 | 20.2 |
| .00120 | .00073 | 26.4 |
| .00060 | .00056 | 121.2 |
| .00116 | .00118 | 145.6 |
| .00197 | .00123 | 216.1 |
| RUPTURE | | 282.5 |

TABLE V. - RESULTS OF CREEP TESTS - CONTINUED

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 124.1 MN/M2 (18.0 KSI) | |
| .00074 | | .3 |
| .00087 | | .4 |
| .00097 | | .6 |
| .00080 | | 1.6 |
| | RUPTURE | 2.8 |
| STRESS - | 103.4 MN/M2 (15.0 KSI) | |
| .00025 | .00028 | .3 |
| .00021 | .00030 | .4 |
| .00033 | .00050 | .5 |
| .00043 | .00085 | 1.4 |
| .00075 | .00110 | 2.8 |
| .00075 | .00110 | 4.2 |
| .00134 | .00230 | 22.1 |
| .00160 | .00210 | 27.9 |
| .00184 | .00253 | 52.2 |
| .00214 | .00333 | 82.8 |
| STRESS - | 82.7 MN/M2 (12.0 KSI) | |
| .00007 | .00025 | .2 |
| .00007 | .00006 | .4 |
| .00024 | .00001 | .7 |
| .00025 | .00013 | 1.6 |
| .00026 | .00005 | 3.5 |
| .00020 | .00001 | 4.7 |
| .00032 | .00013 | 21.0 |
| .00042 | .00014 | 28.8 |
| .00033 | .00030 | 44.6 |
| .00040 | .00003 | 52.6 |
| .00032 | .00017 | 76.4 |
| .00030 | .00042 | 149.5 |
| .00046 | .00047 | 173.7 |
| .00034 | .00045 | 221.1 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1144 K (1600 F)

| STRAIN TOP SPECIMEN | STRAIN BOTTOM SPECIMEN | TIME: HOURS |
|---|---|---|
| STRESS - | 82.7 MN/M2 (12.0 KSI) | |
| .00036 | .00010 | 310.0 |
| .00040 | .00005 | 341.4 |
| .00060 | .00032 | 365.4 |
| .00034 | .00045 | 389.6 |
| .00034 | .00044 | 413.6 |
| .00034 | .00038 | 485.6 |
| .00040 | .00012 | 509.5 |
| .00033 | .00013 | 581.1 |
| .00038 | .00019 | 670.1 |
| .00062 | .00016 | 749.4 |
| .00018 | .00126 | 869.3 |
| .00034 | .00122 | 912.3 |
| .00012 | .00115 | 1013.7 |

TABLE V. - RESULTS OF CREEP TESTS - **Concluded.**

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN | | TIME: |
|---|---|---|
| TOP SPECIMEN | BOTTOM SPECIMEN | HOURS |
| STRESS - | 96.5 MN/M2 | (14.0 KSI) |
| .00008 | .00026 | .2 |
| .00013 | .00053 | .5 |
| .00051 | .00100 | 1.6 |
| .00058 | .00134 | 3.0 |
| .00090 | .00181 | 4.5 |
| | RUPTURE | 14.2 |
| STRESS - | 82.7 MN/M2 | (12.0 KSI) |
| .00002 | .00013 | .3 |
| .00013 | .00025 | .4 |
| .00027 | .00038 | .5 |
| .00024 | .00042 | .7 |
| .00031 | .00037 | .9 |
| .00026 | .00056 | 2.1 |
| .00040 | .00081 | 3.9 |
| .00038 | .00081 | 4.9 |
| RUPTURE | | 16.4 |
| STRESS - | 75.8 MN/M2 | (11.0 KSI) |
| .00029 | .00044 | .3 |
| .00043 | .00100 | .5 |
| .00040 | .00074 | .6 |
| .00060 | .00068 | .7 |
| .00070 | .00069 | 1.5 |
| .00062 | .00050 | 3.3 |
| .00073 | .00086 | 4.5 |
| .00060 | .00007 | 20.5 |
| .00074 | 0.00000 | 28.6 |
| .00073 | .00028 | 45.0 |
| RUPTURE | | 49.3 |

MATERIAL - TD NI-20CR
THICKNESS - .508 MM( .020 IN.)
PRESSURE - .1 KN/M2 ( 1 TORR)
TEMPERATURE - 1255 K (1800 F)

| STRAIN | | TIME: |
|---|---|---|
| TOP SPECIMEN | BOTTOM SPECIMEN | HOURS |
| STRESS - | 68.9 MN/M2 | (10.0 KSI) |
| .00010 | .00004 | .2 |
| .00018 | .00023 | .3 |
| .00030 | .00026 | .6 |
| .00042 | .00020 | 1.3 |
| .00016 | .00048 | 2.5 |
| .00043 | .00074 | 19.0 |
| .00030 | .00078 | 26.9 |
| .00032 | .00085 | 43.0 |
| .00020 | .00094 | 50.8 |
| .00024 | .00092 | 67.3 |
| .00044 | .00084 | 74.7 |
| .00032 | .00110 | 139.2 |
| .00035 | .00123 | 146.7 |
| .00027 | .00150 | 170.7 |
| .00020 | .00157 | 194.6 |
| .00048 | .00167 | 238.8 |
| | RUPTURE | 310.3 |

TABLE VI.- AS-RECEIVED TENSILE PROPERTIES FOR THE SUPERALLOY SHEET MATERIALS

(a) SI Units

| Alloy | Sheet thickness, mm | Tensile strength, $MN/m^2$ | Yield strength, $MN/m^2$ | Modulus of elasticity, $GN/m^2$ | Elongation in 2.54 cm, percent (a) | Elongation in 5.08 cm, percent (b) | Elongation in 2.54 cm, percent (b) |
|---|---|---|---|---|---|---|---|
| René 41 | 0.254 | 1002 | 597 | 200 | 40 | 41 | --- |
| | .254 | 995 | 595 | 200 | 35 | 38 | 42 |
| | .508 | 1007 | 636 | 203 | 40 | 44 | --- |
| | .508 | 997 | 614 | 219 | 44 | 46 | 53 |
| Hastelloy X | .254 | 809 | 505 | 193 | 31 | 32 | 38 |
| | .254 | 804 | 499 | 189 | 30 | 31 | 35 |
| | .508 | 740 | 439 | 192 | 40 | 42 | 45 |
| | .508 | 740 | 435 | 192 | 40 | 44 | 48 |
| Inconel 625 | .254 | 938 | 594 | 201 | 35 | 38 | 43 |
| | .254 | 941 | 593 | 201 | 36 | 40 | 45 |
| | .508 | 948 | 536 | 206 | 40 | 43 | 48 |
| | .508 | 955 | 550 | 206 | 43 | 48 | 53 |
| Inconel 718 | .254 | 965 | 466 | 199 | 37 | 40 | 45 |
| | .254 | 962 | 460 | 192 | 33 | 33 | 44 |
| | .508 | 875 | 384 | 192 | 51 | 52 | 56 |
| | .508 | 875 | 390 | 195 | 48 | 51 | 55 |
| Haynes 25 | .254 | 1007 | 529 | 221 | 37 | 38 | 40 |
| | .254 | 1003 | 525 | 233 | 32 | 33 | 34 |
| | .508 | 940 | 544 | 228 | 30 | 32 | 32 |
| | .508 | 955 | 520 | 231 | 33 | 35 | 37 |
| Haynes 188 | .254 | 942 | 471 | 218 | 53 | 58 | 65 |
| | .254 | 944 | 469 | 209 | 49 | 53 | 60 |
| | .508 | 996 | 523 | 225 | 48 | 56 | 63 |
| | .508 | 999 | 515 | 225 | 49 | 56 | --- |
| TD NiCr | .254 | 880 | 610 | 153 | 13 | 14 | 15 |
| | .254 | 885 | 592 | 153 | 12 | 15 | 16 |
| | .508 | 976 | 665 | 153 | 15 | 18 | 19 |
| | .508 | 947 | 620 | 153 | 15 | 18 | 19 |

[a] Measured adjacent to fracture.
[b] Measured across fracture.

TABLE VI.- AS-RECEIVED TENSILE PROPERTIES FOR THE SUPERALLOY SHEET MATERIALS – Concluded

(b) U.S. Customary Units

| Alloy | Sheet thickness, in. | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent (a) | Elongation in 2 in., percent (b) | Elongation in 1 in., percent (b) |
|---|---|---|---|---|---|---|---|
| René 41 | 0.010 | 145.3 | 86.6 | 29 006.5 | 40 | 41 | --- |
| | .010 | 144.3 | 86.3 | 29 006.5 | 35 | 38 | 42 |
| | .020 | 146.0 | 92.2 | 29 441.6 | 40 | 44 | --- |
| | .020 | 144.6 | 89.1 | 31 762.1 | 44 | 46 | 53 |
| Hastelloy X | .010 | 117.3 | 73.2 | 27 991.3 | 31 | 32 | 38 |
| | .010 | 116.6 | 72.4 | 27 411.2 | 30 | 31 | 35 |
| | .020 | 107.3 | 63.7 | 27 846.3 | 40 | 42 | 45 |
| | .020 | 107.3 | 63.1 | 27 846.3 | 40 | 44 | 48 |
| Inconel 625 | .010 | 136.0 | 86.1 | 29 151.6 | 35 | 38 | 43 |
| | .010 | 136.5 | 86.0 | 29 151.6 | 36 | 40 | 45 |
| | .020 | 137.5 | 77.7 | 29 876.7 | 40 | 43 | 48 |
| | .020 | 138.5 | 79.8 | 29 876.7 | 43 | 48 | 53 |
| Inconel 718 | .010 | 140.0 | 67.6 | 28 861.5 | 37 | 40 | 45 |
| | .010 | 139.5 | 66.7 | 27 846.3 | 33 | 33 | 44 |
| | .020 | 126.9 | 55.7 | 27 846.3 | 51 | 52 | 56 |
| | .020 | 126.9 | 56.6 | 28 281.4 | 48 | 51 | 55 |
| Haynes 25 | .010 | 146.0 | 76.7 | 32 052.2 | 37 | 38 | 40 |
| | .010 | 145.5 | 76.1 | 33 792.6 | 32 | 33 | 34 |
| | .020 | 136.3 | 78.9 | 33 067.4 | 30 | 32 | 32 |
| | .020 | 138.5 | 75.4 | 33 502.5 | 33 | 35 | 37 |
| Haynes 188 | .010 | 136.6 | 68.3 | 31 617.1 | 53 | 58 | 65 |
| | .010 | 136.9 | 68.0 | 30 311.8 | 49 | 53 | 60 |
| | .020 | 144.5 | 75.9 | 32 632.3 | 48 | 56 | 63 |
| | .020 | 144.9 | 74.7 | 32 632.3 | 49 | 56 | --- |
| TD NiCr | .010 | 127.6 | 88.5 | 22 190.0 | 13 | 14 | 15 |
| | .010 | 128.4 | 85.9 | 22 190.0 | 12 | 15 | 16 |
| | .020 | 141.6 | 96.4 | 22 190.0 | 15 | 18 | 19 |
| | .020 | 137.3 | 89.9 | 22 190.0 | 15 | 18 | 19 |

[a] Measured adjacent to fracture.
[b] Measured across fracture.

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS

(a) SI Units

| Sheet thickness mm | Creep stress, $MN/m^2$ | Creep exposure, hr | Creep strain, percent | Tensile strength, $MN/m^2$ | Yield strength, $MN/m^2$ | Modulus of elasticity, $GN/m^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, $kN/m^2$ |
|---|---|---|---|---|---|---|---|---|---|
| René 41 | | | | | | | | | |
| .508 | 276.0 | 193.0 | .538 | 1371.0 | 1080.0 | 212.0 | | 1033 | 1.07 |
| .508 | 276.0 | 193.0 | | 1329.0 | 1070.0 | 208.0 | 10 | 1033 | 1.07 |
| .508 | 207.0 | 675.0 | .596 | 1297.0 | 1023.0 | 212.0 | 7 | 1033 | 1.07 |
| .508 | 207.0 | 675.0 | .889 | 1297.0 | 1012.0 | 209.0 | 9 | 1033 | 1.07 |
| .508 | 138.0 | 1876.4 | .499 | | | | | 1033 | 1.07 |
| .508 | 138.0 | 1876.4 | .603 | | | | | 1033 | 1.07 |
| .508 | 69.0 | 5003.4 | .504 | 1102.0 | 842.0 | 214.0 | 4 | 1033 | 1.07 |
| .508 | 69.0 | 5003.4 | .464 | 1168.0 | 897.0 | 217.0 | 4 | 1033 | 1.07 |
| | | | | | | | | | |
| .254 | 207.0 | .2 | | | | | | 1033 | 1.07 |
| .254 | 207.0 | .2 | | 1327.0 | 1015.0 | 213.0 | 16 | 1033 | 1.07 |
| .254 | 173.0 | 312.6 | .896 | 1067.0 | 908.0 | 213.0 | 4 | 1033 | 1.07 |
| .254 | 173.0 | 312.6 | .838 | 1039.0 | 918.0 | 214.0 | 2 | 1033 | 1.07 |
| .254 | 138.0 | 316.0 | .500 | 1160.0 | 888.0 | 214.0 | 6 | 1033 | 1.07 |
| .254 | 138.0 | 316.0 | .526 | 1202.0 | 905.0 | 215.0 | 10 | 1033 | 1.07 |
| .254 | 104.0 | 551.5 | .400 | 1211.0 | 925.0 | 218.0 | 7 | 1033 | 1.07 |
| .254 | 104.0 | 551.5 | .762 | 1131.0 | 859.0 | 216.0 | 7 | 1033 | 1.07 |
| .254 | 69.0 | 3716.0 | .533 | 1020.0 | 844.0 | 213.0 | 3 | 1033 | 1.07 |
| .254 | 69.0 | 3716.0 | .706 | 955.0 | 726.0 | 213.0 | 3 | 1033 | 1.07 |
| | | | | | | | | | |
| .508 | 69.0 | 1.3 | .579 | 1215.0 | 738.0 | 208.0 | 28 | 1256 | 1.07 |
| .508 | 69.0 | 1.3 | 1.257 | 1170.0 | 710.0 | 204.0 | 24 | 1256 | 1.07 |
| .508 | 21.0 | 19.4 | .552 | 1100.0 | 698.0 | 210.0 | | 1256 | 1.07 |
| .508 | 21.0 | 19.4 | 1.080 | 1128.0 | 705.0 | 210.0 | 25 | 1256 | 1.07 |
| | | | | | | | | | |
| .254 | 69.0 | 1.7 | | 1108.0 | 681.0 | 213.0 | 21 | 1256 | 1.07 |
| .254 | 69.0 | 1.7 | 1.070 | 1120.0 | 689.0 | 217.0 | 23 | 1256 | 1.07 |
| .254 | 21.0 | 42.8 | .700 | 947.0 | 628.0 | 218.0 | 10 | 1256 | 1.07 |
| .254 | 21.0 | 42.8 | .715 | 989.0 | 637.0 | 214.0 | 12 | 1256 | 1.07 |
| | | | | | | | | | |
| .508 | 104.0 | 45.8 | .230 | 1230.0 | 868.0 | 205.0 | 12 | 1145 | .13 |
| .508 | 104.0 | 45.8 | .800 | 1096.0 | 798.0 | 207.0 | 9 | 1145 | .13 |
| .508 | 83.0 | 116.9 | .650 | 990.0 | 738.0 | 213.0 | 4 | 1145 | .13 |
| .508 | 83.0 | 116.9 | .380 | 1156.0 | 778.0 | 214.0 | 12 | 1145 | .13 |
| .508 | 69.0 | 125.1 | .545 | 988.0 | 746.0 | 214.0 | 9 | 1145 | .13 |
| .508 | 69.0 | 125.1 | 1.096 | 1040.0 | 685.0 | 207.0 | 9 | 1145 | .13 |
| .508 | 62.0 | 172.5 | .327 | 1043.0 | 744.0 | 212.0 | 3 | 1145 | .13 |
| .508 | 62.0 | 172.5 | .674 | 1003.0 | 691.0 | 208.0 | 7 | 1145 | .13 |
| .508 | 59.0 | 245.2 | .448 | 1002.0 | 716.0 | 208.0 | 7 | 1145 | .13 |
| .508 | 59.0 | 245.2 | .625 | 1023.0 | 664.0 | 205.0 | 10 | 1145 | .13 |
| .508 | 52.0 | 298.6 | .346 | 1041.0 | 671.0 | 206.0 | 10 | 1145 | .13 |
| .508 | 52.0 | 298.6 | .906 | 994.0 | 622.0 | 200.0 | 9 | 1145 | .13 |
| | | | | | | | | | |
| .508 | 21.0 | 18.9 | .670 | 1101.0 | 715.0 | 212.0 | 16 | 1256 | .13 |
| .508 | 21.0 | 18.9 | 1.424 | 1116.0 | 705.0 | 210.0 | ~~0~~ | 1256 | .13 |
| .508 | 21.0 | 26.4 | .491 | 1149.0 | 707.0 | 209.0 | 25 | 1256 | .13 |
| .508 | 21.0 | 26.4 | .979 | 1113.0 | 707.0 | 213.0 | 24 | 1256 | .13 |
| .508 | 14.0 | 69.0 | .852 | 1048.0 | 668.0 | 214.0 | 25 | 1256 | .13 |
| .508 | 14.0 | 69.0 | .567 | 1053.0 | 673.0 | 212.0 | | 1256 | .13 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(a) SI Units – Continued

| Sheet thickness, mm | Creep stress, MN/m² | Creep exposure, hr | Creep strain, percent | Tensile strength, MN/m² | Yield strength, MN/m² | Modulus of elasticity, GN/m² | Elongation in 2.54 cm, percent | Temperature, K | Pressure kN/m² |
|---|---|---|---|---|---|---|---|---|---|
| Hastelloy X | | | | | | | | | |
| .508 | 138.0 | 24.2 | 2.091 | 775.0 | 442.0 | 188.0 | 13 | 1033 | 1.07 |
| .508 | 138.0 | 24.2 | 2.094 | 842.0 | 450.0 | 191.0 | 24 | 1033 | 1.07 |
| .508 | 104.0 | 50.9 | .878 | 834.0 | 404.0 | 183.0 | 21 | 1033 | 1.07 |
| .508 | 104.0 | 50.9 | .811 | 831.0 | 411.0 | 188.0 | 25 | 1033 | 1.07 |
| .508 | 69.0 | 183.1 | .419 | 864.0 | 408.0 | 194.0 | 29 | 1033 | 1.07 |
| .508 | 69.0 | 183.1 | .790 | 848.0 | 405.0 | 195.0 | 20 | 1033 | 1.07 |
| .508 | 52.0 | 1029.0 | .528 | 859.0 | 414.0 | 192.0 | 18 | 1033 | 1.07 |
| .508 | 52.0 | 1029.0 | | 854.0 | 415.0 | 211.0 | 18 | 1033 | 1.07 |
| .508 | 34.0 | 2972.2 | .400 | 795.0 | 407.0 | 204.0 | 11 | 1033 | 1.07 |
| .508 | 34.0 | 2972.2 | .594 | 790.0 | 396.0 | 201.0 | 11 | 1033 | 1.07 |
| Inconel 625 | | | | | | | | | |
| .508 | 138.0 | 27.3 | 2.796 | 975.0 | 583.0 | 200.0 | 41 | 1033 | 1.07 |
| .508 | 138.0 | 27.3 | 2.795 | 975.0 | 590.0 | 201.0 | 37 | 1033 | 1.07 |
| .508 | 104.0 | 117.4 | 2.111 | 1046.0 | 628.0 | 201.0 | 35 | 1033 | 1.07 |
| .508 | 104.0 | 117.4 | 2.398 | 1042.0 | 632.0 | 200.0 | 35 | 1033 | 1.07 |
| .508 | 69.0 | 160.6 | .546 | 1048.0 | 615.0 | 205.0 | 40 | 1033 | 1.07 |
| .508 | 69.0 | 160.6 | .662 | 1051.0 | 623.0 | 205.0 | 38 | 1033 | 1.07 |
| .508 | 52.0 | 342.4 | 1.076 | 1060.0 | 638.0 | 203.0 | 35 | 1033 | 1.07 |
| .508 | 52.0 | 342.4 | .608 | 1063.0 | 656.0 | 204.0 | 33 | 1033 | 1.07 |
| .508 | 34.0 | 2397.9 | .749 | 1032.0 | 588.0 | 202.0 | 35 | 1033 | 1.07 |
| .508 | 34.0 | 2397.9 | .518 | 1032.0 | | | 35 | 1033 | 1.07 |
| Inconel 718 | | | | | | | | | |
| .508 | 276.0 | 21.1 | .890 | 1230.0 | 935.0 | 210.0 | 17 | 1033 | 1.07 |
| .508 | 276.0 | 21.1 | .129 | 1260.0 | 978.0 | 210.0 | 11 | 1033 | 1.07 |
| .508 | 207.0 | 119.7 | 2.192 | 820.0 | 771.0 | 192.0 | 2 | 1033 | 1.07 |
| .508 | 207.0 | 119.7 | .656 | 1190.0 | 865.0 | 204.0 | 20 | 1033 | 1.07 |
| .508 | 138.0 | 307.0 | 2.090 | 1050.0 | 676.0 | 204.0 | 22 | 1033 | 1.07 |
| .508 | 138.0 | 307.0 | .798 | 1100.0 | 736.0 | 203.0 | 12 | 1033 | 1.07 |
| .508 | 69.0 | 645.0 | .550 | 1035.0 | 646.0 | 196.0 | 26 | 1033 | 1.07 |
| .508 | 69.0 | 645.0 | .955 | | | | | 1033 | 1.07 |
| .508 | 52.0 | 849.6 | .591 | 970.0 | 667.0 | 208.0 | 15 | 1033 | 1.07 |
| .508 | 52.0 | 849.6 | .519 | 1000.0 | 666.0 | 204.0 | 16 | 1033 | 1.07 |
| .508 | 34.0 | 1974.9 | .653 | 915.0 | 666.0 | 200.0 | 7 | 1033 | 1.07 |
| .508 | 34.0 | 1974.9 | .407 | 922.0 | 667.0 | 201.0 | 9 | 1033 | 1.07 |
| Haynes 25 | | | | | | | | | |
| .508 | 138.0 | 23.6 | 1.291 | 846.0 | 531.0 | 228.0 | 22 | 1033 | 1.07 |
| .508 | 138.0 | 23.6 | 1.062 | 835.0 | 538.0 | 232.0 | 29 | 1033 | 1.07 |
| .508 | 104.0 | 167.0 | 1.929 | 810.0 | 516.0 | 232.0 | 20 | 1033 | 1.07 |
| .508 | 104.0 | 167.0 | 1.353 | 790.0 | 515.0 | 232.0 | 17 | 1033 | 1.07 |
| .508 | 69.0 | 427.0 | .703 | 760.0 | 486.0 | 223.0 | 15 | 1033 | 1.07 |
| .508 | 69.0 | 427.0 | .555 | 810.0 | 494.0 | 240.0 | 18 | 1033 | 1.07 |
| .508 | 52.0 | 1486.4 | .723 | | | | | 1033 | 1.07 |
| .508 | 52.0 | 1486.4 | .480 | | | | | 1033 | 1.07 |
| .508 | 34.0 | 5352.5 | .577 | 800.0 | 554.0 | 236.0 | 8 | 1033 | 1.07 |
| .508 | 34.0 | 5352.5 | .673 | 842.0 | 583.0 | 242.0 | 6 | 1033 | 1.07 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(a) SI Units – Continued

| Sheet thickness, mm | Creep stress, MN/m$^2$ | Creep exposure, hr | Creep strain, percent | Tensile strength, MN/m$^2$ | Yield strength, MN/m$^2$ | Modulus of elasticity, GN/m$^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Haynes 188 | | | | | | | | | |
| .508 | 104.0 | 50.3 | .663 | 955.0 | 495.0 | 218.0 | 37 | 1033 | 1.07 |
| .508 | 104.0 | 50.3 | .454 | 986.0 | 508.0 | 224.0 | 47 | 1033 | 1.07 |
| .508 | 69.0 | 1198.9 | .590 | 834.0 | 487.0 | 227.0 | 10 | 1033 | 1.07 |
| .508 | 69.0 | 1198.9 | .574 | 895.0 | 485.0 | 228.0 | 16 | 1033 | 1.07 |
| .508 | 52.0 | 2040.0 | .494 | 934.0 | 487.0 | 228.0 | 15 | 1033 | 1.07 |
| .508 | 52.0 | 2040.0 | .553 | 962.0 | 507.0 | 239.0 | 11 | 1033 | 1.07 |
| .508 | 34.0 | 3500.5 | .462 | 885.0 | 514.0 | 234.0 | 9 | 1033 | 1.07 |
| .508 | 34.0 | 3500.5 | -0.000 | 908.0 | 525.0 | 234.0 | 6 | 1033 | 1.07 |
| .254 | 104.0 | 25.1 | .790 | 880.0 | 501.0 | 233.0 | 32 | 1033 | 1.07 |
| .254 | 104.0 | 25.1 | .564 | 910.0 | 495.0 | 229.0 | 42 | 1033 | 1.07 |
| .254 | 69.0 | 146.3 | .794 | 854.0 | 474.0 | 225.0 | 31 | 1033 | 1.07 |
| .254 | 69.0 | 146.3 | .535 | 892.0 | 481.0 | 232.0 | 38 | 1033 | 1.07 |
| .254 | 52.0 | 602.3 | .394 | 760.0 | 461.0 | 240.0 | 12 | 1033 | 1.07 |
| .254 | 52.0 | 602.3 | .628 | 784.0 | 463.0 | 230.0 | 13 | 1033 | 1.07 |
| .508 | 69.0 | .3 | 1.560 | 940.0 | 455.0 | 228.0 | 42 | 1256 | 1.07 |
| .508 | 69.0 | .3 | .827 | 950.0 | 461.0 | 230.0 | 46 | 1256 | 1.07 |
| .508 | 52.0 | 1.3 | | 960.0 | 447.0 | 233.0 | 47 | 1256 | 1.07 |
| .508 | 52.0 | 1.3 | .424 | 948.0 | 446.0 | 229.0 | 46 | 1256 | 1.07 |
| .508 | 34.0 | 19.3 | 1.653 | 920.0 | 425.0 | 228.0 | 31 | 1256 | 1.07 |
| .508 | 34.0 | 19.3 | 4.134 | 886.0 | 419.0 | 224.0 | 29 | 1256 | 1.07 |
| .508 | 21.0 | 50.2 | .535 | 925.0 | 415.0 | 226.0 | 39 | 1256 | 1.07 |
| .508 | 21.0 | 50.2 | .361 | 940.0 | 425.0 | 232.0 | 40 | 1256 | 1.07 |
| .254 | 52.0 | .9 | .880 | 906.0 | | 232.0 | 50 | 1256 | 1.07 |
| .254 | 52.0 | .9 | .636 | 894.0 | 447.0 | 220.0 | 38 | 1256 | 1.07 |
| .254 | 34.0 | 26.7 | .631 | 808.0 | 411.0 | 231.0 | 19 | 1256 | 1.07 |
| .254 | 34.0 | 26.7 | .066 | 826.0 | 426.0 | 240.0 | 20 | 1256 | 1.07 |
| .254 | 21.0 | 43.0 | .482 | 855.0 | 439.0 | 228.0 | 19 | 1256 | 1.07 |
| .254 | 21.0 | 43.0 | .785 | 811.0 | 405.0 | 231.0 | 18 | 1256 | 1.07 |
| .508 | 104.0 | 93.6 | .948 | 895.0 | 516.0 | 232.0 | 26 | 1033 | .13 |
| .508 | 104.0 | 93.6 | .594 | 924.0 | 512.0 | 242.0 | 33 | 1033 | .13 |
| .508 | 55.0 | 70.3 | .433 | 935.0 | 456.0 | 234.0 | 32 | 1144 | .13 |
| .508 | 55.0 | 70.3 | .648 | 931.0 | 448.0 | 231.0 | 30 | 1144 | .13 |
| .508 | 48.0 | 244.5 | .513 | 935.0 | 465.0 | 246.0 | 18 | 1144 | .13 |
| .508 | 48.0 | 244.5 | .700 | 865.0 | 458.0 | 229.0 | 13 | 1144 | .13 |
| .508 | 41.0 | 525.1 | .490 | 935.0 | 449.0 | 227.0 | 13 | 1144 | .13 |
| .508 | 41.0 | 525.1 | .467 | 920.0 | 455.0 | 234.0 | 10 | 1144 | .13 |
| .508 | 28.0 | 50.3 | .574 | 941.0 | 424.0 | 232.0 | 25 | 1256 | .13 |
| .508 | 28.0 | 50.3 | .470 | 941.0 | 424.0 | 232.0 | 38 | 1256 | .13 |
| .508 | 28.0 | 49.5 | .143 | 875.0 | 411.0 | 232.0 | 27 | 1256 | .13 |
| .508 | 28.0 | 49.5 | .676 | 875.0 | 416.0 | 232.0 | 26 | 1256 | .13 |
| .508 | 24.0 | 188.8 | .412 | 924.0 | 414.0 | 225.0 | 24 | 1256 | .13 |
| .508 | 24.0 | 188.8 | .638 | 924.0 | 401.0 | 228.0 | 31 | 1256 | .13 |
| .508 | 24.0 | 117.6 | .597 | 905.0 | 401.0 | 232.0 | 25 | 1256 | .13 |
| .508 | 24.0 | 117.6 | .934 | 897.0 | 408.0 | 232.0 | 29 | 1256 | .13 |
| .508 | 21.0 | 212.9 | .532 | 913.0 | 421.0 | 232.0 | 28 | 1256 | .13 |
| .508 | 21.0 | 212.9 | .449 | 908.0 | 430.0 | 228.0 | 26 | 1256 | .13 |
| .508 | 21.0 | 165.0 | .375 | 915.0 | 401.0 | 229.0 | 24 | 1256 | .13 |
| .508 | 21.0 | 165.0 | 1.153 | 884.0 | 384.0 | 226.0 | 28 | 1256 | .13 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(a) SI Units – Concluded

| Sheet thickness, mm | Creep stress, MN/m$^2$ | Creep exposure, hr | Creep strain, percent | Tensile strength, MN/m$^2$ | Yield strength, MN/m$^2$ | Modulus of elasticity, GN/m$^2$ | Elongation in 2.54 cm. percent | Temperature K | Pressure, kN/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| TD NiCr | | | | | | | | | |
| .508 | 138.0 | 60.0 | | | | | | 1033 | 1.07 |
| .508 | 138.0 | 60.0 | .214 | 697.0 | 660.0 | 169.0 | 2 | 1033 | 1.07 |
| .508 | 138.0 | 43.0 | .246 | 861.0 | 635.0 | 163.0 | 9 | 1033 | 1.07 |
| .508 | 138.0 | 43.0 | .610 | 379.0 | | 157.0 | 1 | 1033 | 1.07 |
| .508 | 121.0 | 1171.9 | | | | | | 1033 | 1.07 |
| .508 | 121.0 | 1171.9 | .174 | 825.0 | 625.0 | 162.0 | 7 | 1033 | 1.07 |
| .508 | 121.0 | 31.1 | | | | | | 1033 | 1.07 |
| .508 | 121.0 | 31.1 | .055 | 935.0 | 612.0 | 159.0 | 21 | 1033 | 1.07 |
| .508 | 104.0 | 5008.7 | .167 | 716.0 | 621.0 | 168.0 | 5 | 1033 | 1.07 |
| .508 | 104.0 | 5008.7 | .264 | 854.0 | 616.0 | 166.0 | 10 | 1033 | 1.07 |
| .508 | 69.0 | 3836.3 | .089 | 907.0 | 615.0 | 162.0 | 14 | 1033 | 1.07 |
| .508 | 69.0 | 3836.3 | .068 | 904.0 | 600.0 | 164.0 | 15 | 1033 | 1.07 |
| .254 | 138.0 | 26.4 | .590 | 336.0 | | 155.0 | 2 | 1033 | 1.07 |
| .254 | 138.0 | 26.4 | .309 | 516.0 | | 157.0 | 2 | 1033 | 1.07 |
| .254 | 121.0 | 546.5 | .243 | | | | | 1033 | 1.07 |
| .254 | 121.0 | | | | | | | 1033 | 1.07 |
| .254 | 104.0 | 1578.9 | .040 | 715.0 | 591.0 | 153.0 | 2 | 1033 | 1.07 |
| .254 | 104.0 | 1578.9 | .044 | 617.0 | 589.0 | 156.0 | 2 | 1033 | 1.07 |
| .254 | 69.0 | 2034.4 | .041 | 760.0 | 578.0 | 156.0 | 6 | 1033 | 1.07 |
| .254 | 69.0 | 2034.4 | .036 | 754.0 | 585.0 | 154.0 | 2 | 1033 | 1.07 |
| .508 | 138.0 | 0.0 | | 764.0 | 670.0 | 161.0 | 2 | 1256 | 1.07 |
| .508 | 138.0 | 0.0 | | | | | | 1256 | 1.07 |
| .508 | 121.0 | .1 | | 625.0 | 616.0 | 161.0 | 2 | 1256 | 1.07 |
| .508 | 121.0 | .1 | | | | | | 1256 | 1.07 |
| .508 | 104.0 | .2 | | 700.0 | 645.0 | 167.0 | 3 | 1256 | 1.07 |
| .508 | 104.0 | .2 | | | | | | 1256 | 1.07 |
| .508 | 90.0 | .5 | .139 | 806.0 | 619.0 | 162.0 | 7 | 1256 | 1.07 |
| .508 | 90.0 | .5 | | | | | | 1256 | 1.07 |
| .508 | 69.0 | 145.7 | .059 | 454.0 | | 161.0 | 3 | 1256 | 1.07 |
| .508 | 69.0 | 145.7 | | | | | | 1256 | 1.07 |
| .508 | 62.0 | 3.4 | .026 | 754.0 | 623.0 | 165.0 | 6 | 1256 | 1.07 |
| .508 | 62.0 | 3.4 | | | | | | 1256 | 1.07 |
| .508 | 55.0 | 1149.6 | .081 | 750.0 | 611.0 | 163.0 | 6 | 1256 | 1.07 |
| .508 | 55.0 | 1149.6 | | | | | | 1256 | 1.07 |
| .508 | 52.0 | 2087.4 | .217 | 609.0 | | 172.0 | 2 | 1256 | 1.07 |
| .508 | 52.0 | 2087.4 | | | | | | 1256 | 1.07 |
| .508 | 34.0 | 1491.3 | .006 | 849.0 | 626.0 | 167.0 | 8 | 1256 | 1.07 |
| .508 | 34.0 | 1491.3 | .050 | 707.0 | 620.0 | 161.0 | 4 | 1256 | 1.07 |
| .508 | 34.0 | 2660.0 | .043 | 919.0 | 664.0 | 168.0 | 11 | 1256 | 1.07 |
| .508 | 34.0 | 2660.0 | | 805.0 | 626.0 | 162.0 | 6 | 1256 | 1.07 |
| .254 | 104.0 | 3.3 | .276 | 437.0 | | 151.0 | | 1256 | 1.07 |
| .254 | 104.0 | 3.3 | | | | | | 1256 | 1.07 |
| .254 | 69.0 | 282.5 | .128 | | | | | 1256 | 1.07 |
| .254 | 69.0 | 282.5 | | | | | | 1256 | 1.07 |
| .508 | 124.0 | 2.8 | .080 | 940.0 | 633.0 | 161.0 | 13 | 1144 | .13 |
| .508 | 124.0 | 2.8 | | | | | | 1144 | .13 |
| .508 | 104.0 | 82.8 | .214 | 591.0 | | 162.0 | 2 | 1144 | .13 |
| .508 | 104.0 | 82.8 | | | | | | 1144 | .13 |
| .508 | 83.0 | 1013.7 | .012 | 896.0 | 624.0 | 163.0 | 10 | 1144 | .13 |
| .508 | 83.0 | 1013.7 | .115 | 728.0 | 618.0 | 163.0 | 4 | 1144 | .13 |
| .508 | 97.0 | 14.2 | .090 | 840.0 | 635.0 | 159.0 | 7 | 1256 | .13 |
| .508 | 97.0 | 14.2 | | | | | | 1256 | .13 |
| .508 | 83.0 | 16.4 | .081 | 845.0 | 614.0 | 161.0 | 9 | 1256 | .13 |
| .508 | 83.0 | 16.4 | | | | | | 1256 | .13 |
| .508 | 76.0 | 49.3 | .028 | 877.0 | 605.0 | 165.0 | 12 | 1256 | .13 |
| .508 | 76.0 | 49.3 | | | | | | 1256 | .13 |
| .508 | 69.0 | 310.3 | .048 | 765.0 | 600.0 | 157.0 | 4 | 1256 | .13 |
| .508 | 69.0 | 310.3 | | | | | | 1256 | .13 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(b) U.S. Customary Units

| Sheet thickness, in. | Creep stress, ksi | Creep exposure, hr | Creep strain, percent | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|---|
| René 41 | | | | | | | | | |
| .020 | 40.0 | 193.0 | .538 | 198.8 | 156.6 | 30746.9 | | 1400 | 8 |
| .020 | 40.0 | 193.0 | | 192.7 | 155.2 | 30166.8 | 10 | 1400 | 8 |
| .020 | 30.0 | 675.0 | .596 | 138.1 | 148.4 | 30746.9 | 7 | 1400 | 8 |
| .020 | 30.0 | 675.0 | .889 | 188.1 | 146.8 | 30311.8 | 9 | 1400 | 8 |
| .020 | 20.0 | 1876.4 | .499 | | | | | 1400 | 8 |
| .020 | 20.0 | 1876.4 | .603 | | | | | 1400 | 8 |
| .020 | 10.0 | 5003.4 | .504 | 159.8 | 122.1 | 31037.0 | 4 | 1400 | 8 |
| .020 | 10.0 | 5003.4 | .464 | 169.4 | 130.1 | 31472.1 | 4 | 1400 | 8 |
| | | | | | | | | | |
| .010 | 30.0 | .2 | | | | | | 1400 | 8 |
| .010 | 30.0 | .2 | | 192.5 | 147.2 | 30892.0 | 16 | 1400 | 8 |
| .010 | 25.1 | 312.6 | .896 | 154.7 | 131.7 | 30892.0 | 4 | 1400 | 8 |
| .010 | 25.1 | 312.6 | .833 | 150.7 | 133.1 | 31037.0 | 2 | 1400 | 8 |
| .010 | 20.0 | 316.0 | .500 | 168.2 | 128.8 | 31037.0 | 6 | 1400 | 8 |
| .010 | 20.0 | 316.0 | .526 | 174.3 | 131.3 | 31327.0 | 10 | 1400 | 8 |
| .010 | 15.1 | 551.5 | .400 | 175.6 | 134.2 | 31617.1 | 7 | 1400 | 8 |
| .010 | 15.1 | 551.5 | .762 | 164.0 | 124.6 | 31327.0 | 7 | 1400 | 8 |
| .010 | 10.0 | 3716.0 | .533 | 147.9 | 122.4 | 30892.0 | 3 | 1400 | 8 |
| .010 | 10.0 | 3716.0 | .706 | 138.5 | 105.3 | 30892.0 | 3 | 1400 | 8 |
| | | | | | | | | | |
| .020 | 10.0 | 1.3 | .579 | 176.2 | 107.0 | 30166.8 | 28 | 1800 | 8 |
| .020 | 10.0 | 1.3 | 1.257 | 169.7 | 103.0 | 29585.7 | 24 | 1800 | 8 |
| .020 | 3.0 | 19.4 | .552 | 159.5 | 101.2 | 30456.9 | | 1800 | 8 |
| .020 | 3.0 | 19.4 | 1.080 | 163.6 | 102.2 | 30456.9 | 25 | 1800 | 8 |
| | | | | | | | | | |
| .010 | 10.0 | 1.7 | | 160.7 | 98.8 | 30892.0 | 21 | 1800 | 8 |
| .010 | 10.0 | 1.7 | 1.070 | 162.4 | 99.9 | 31472.1 | 23 | 1800 | 8 |
| .010 | 3.0 | 42.8 | .700 | 137.3 | 91.1 | 31617.1 | 10 | 1800 | 8 |
| .010 | 3.0 | 42.8 | .715 | 143.4 | 92.4 | 31037.0 | 12 | 1800 | 8 |
| | | | | | | | | | |
| .020 | 15.1 | 45.8 | .230 | 178.4 | 125.9 | 29731.7 | 12 | 1600 | 1 |
| .020 | 15.1 | 45.8 | .800 | 159.0 | 115.7 | 30021.8 | 9 | 1600 | 1 |
| .020 | 12.0 | 116.9 | .650 | 143.6 | 107.0 | 30892.0 | 4 | 1600 | 1 |
| .020 | 12.0 | 116.9 | .380 | 167.7 | 112.8 | 31037.0 | 12 | 1600 | 1 |
| .020 | 10.0 | 125.1 | .545 | 143.3 | 108.2 | 31037.0 | 9 | 1600 | 1 |
| .020 | 10.0 | 125.1 | 1.096 | 150.8 | 99.3 | 30021.8 | 9 | 1600 | 1 |
| .020 | 9.0 | 172.5 | .327 | 151.3 | 107.9 | 30746.9 | 3 | 1600 | 1 |
| .020 | 9.0 | 172.5 | .674 | 145.5 | 100.2 | 30166.8 | 7 | 1600 | 1 |
| .020 | 8.6 | 245.2 | .448 | 145.3 | 103.8 | 30165.8 | 7 | 1600 | 1 |
| .020 | 8.6 | 245.2 | .625 | 148.4 | 96.3 | 29731.7 | 10 | 1600 | 1 |
| .020 | 7.5 | 298.6 | .346 | 151.0 | 97.3 | 29876.7 | 10 | 1600 | 1 |
| .020 | 7.5 | 298.6 | .906 | 144.2 | 90.2 | 29006.5 | 9 | 1600 | 1 |
| | | | | | | | | | |
| .020 | 3.0 | 18.9 | .670 | 159.7 | 103.7 | 30746.9 | 16 | 1800 | 1 |
| .020 | 3.0 | 18.9 | 1.424 | 161.9 | 102.2 | 30456.9 | | 1800 | 1 |
| .020 | 3.0 | 26.4 | .491 | 166.6 | 102.5 | 30311.8 | 25 | 1800 | 1 |
| .020 | 3.0 | 26.4 | .979 | 161.4 | 102.5 | 30892.0 | 24 | 1800 | 1 |
| .020 | 2.0 | 69.0 | .852 | 152.0 | 96.9 | 31037.0 | 25 | 1800 | 1 |
| .020 | 2.0 | 69.0 | .567 | 152.7 | 97.6 | 30746.9 | | 1800 | 1 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(b) U.S. Customary Units – Continued

| Sheet thickness, in. | Creep stress, ksi | Creep exposure, hr | Creep strain, percent | Tensile strength, ksi. | Yield strength, ksi. | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|---|
| Hastelloy X | | | | | | | | | |
| .020 | 20.0 | 24.2 | 2.091 | 112.4 | 64.1 | 27266.1 | 13 | 1400 | 8 |
| .020 | 20.0 | 24.2 | 2.094 | 122.1 | 65.3 | 27731.2 | 24 | 1400 | 8 |
| .020 | 15.1 | 50.9 | .878 | 121.0 | 58.6 | 26541.0 | 21 | 1400 | 8 |
| .020 | 15.1 | 50.9 | .811 | 120.5 | 59.6 | 27266.1 | 25 | 1400 | 8 |
| .020 | 10.0 | 183.1 | .419 | 125.3 | 59.2 | 28136.3 | 29 | 1400 | 8 |
| .020 | 10.0 | 183.1 | .790 | 123.0 | 58.7 | 28281.4 | 20 | 1400 | 8 |
| .020 | 7.5 | 1029.0 | .528 | 124.6 | 60.0 | 27846.3 | 18 | 1400 | 8 |
| .020 | 7.5 | 1029.0 | | 123.9 | 60.2 | 30601.9 | 18 | 1400 | 8 |
| .020 | 4.9 | 2972.2 | .400 | 115.3 | 59.0 | 29586.7 | 11 | 1400 | 8 |
| .020 | 4.9 | 2972.2 | .594 | 114.6 | 57.4 | 29151.6 | 11 | 1400 | 8 |
| Inconel 625 | | | | | | | | | |
| .020 | 20.0 | 27.3 | 2.796 | 141.4 | 84.6 | 29006.5 | 41 | 1400 | 8 |
| .020 | 20.0 | 27.3 | 2.795 | 141.4 | 85.6 | 29151.6 | 37 | 1400 | 8 |
| .020 | 15.1 | 117.4 | 2.111 | 151.7 | 91.1 | 29151.6 | 35 | 1400 | 8 |
| .020 | 15.1 | 117.4 | 2.398 | 151.1 | 91.7 | 29006.5 | 35 | 1400 | 8 |
| .020 | 10.0 | 160.6 | .546 | 152.0 | 89.2 | 29731.7 | 40 | 1400 | 8 |
| .020 | 10.0 | 160.6 | .662 | 152.4 | 90.4 | 29731.7 | 38 | 1400 | 8 |
| .020 | 7.5 | 342.4 | 1.076 | 153.7 | 92.5 | 29441.6 | 35 | 1400 | 8 |
| .020 | 7.5 | 342.4 | .608 | 154.2 | 95.1 | 29586.7 | 33 | 1400 | 8 |
| .020 | 4.9 | 2397.9 | .749 | 149.7 | 85.3 | 29296.6 | 35 | 1400 | 8 |
| .020 | 4.9 | 2397.9 | .518 | 149.7 | | | 35 | 1400 | 8 |
| Inconel 718 | | | | | | | | | |
| .020 | 40.0 | 21.1 | .890 | 178.4 | 135.6 | 30456.9 | 17 | 1400 | 8 |
| .020 | 40.0 | 21.1 | .129 | 182.7 | 141.8 | 30456.9 | 11 | 1400 | 8 |
| .020 | 30.0 | 119.7 | 2.192 | 118.9 | 111.8 | 27845.3 | 2 | 1400 | 8 |
| .020 | 30.0 | 119.7 | .656 | 172.6 | 125.5 | 29586.7 | 20 | 1400 | 8 |
| .020 | 20.0 | 307.0 | 2.090 | 152.3 | 98.0 | 29585.7 | 22 | 1400 | 8 |
| .020 | 20.0 | 307.0 | .798 | 159.5 | 106.7 | 29441.6 | 12 | 1400 | 8 |
| .020 | 10.0 | 645.0 | .550 | 150.1 | 93.7 | 28426.4 | 26 | 1400 | 8 |
| .020 | 10.0 | 645.0 | .955 | | | | | 1400 | 8 |
| .020 | 7.5 | 849.6 | .591 | 140.7 | 96.7 | 30156.8 | 15 | 1400 | 8 |
| .020 | 7.5 | 849.6 | .519 | 145.0 | 96.6 | 29586.7 | 16 | 1400 | 8 |
| .020 | 4.9 | 1974.9 | .653 | 132.7 | 96.6 | 29006.5 | 7 | 1400 | 8 |
| .020 | 4.9 | 1974.9 | .407 | 133.7 | 96.7 | 29151.6 | 9 | 1400 | 8 |
| Haynes 25 | | | | | | | | | |
| .020 | 20.0 | 23.6 | 1.291 | 122.7 | 77.0 | 33067.4 | 22 | 1400 | 8 |
| .020 | 20.0 | 23.6 | 1.062 | 121.1 | 78.0 | 33647.6 | 29 | 1400 | 8 |
| .020 | 15.1 | 167.0 | 1.929 | 117.5 | 74.8 | 33647.6 | 20 | 1400 | 8 |
| .020 | 15.1 | 167.0 | 1.353 | 114.6 | 74.7 | 33647.6 | 17 | 1400 | 8 |
| .020 | 10.0 | 427.0 | .703 | 110.2 | 70.5 | 32342.3 | 15 | 1400 | 8 |
| .020 | 10.0 | 427.0 | .555 | 117.5 | 71.6 | 34807.8 | 18 | 1400 | 8 |
| .020 | 7.5 | 1486.4 | .723 | | | | | 1400 | 8 |
| .020 | 7.5 | 1486.4 | .480 | | | | | 1400 | 8 |
| .020 | 4.9 | 5352.5 | .577 | 116.0 | 80.3 | 34227.7 | 8 | 1400 | 8 |
| .020 | 4.9 | 5352.5 | .673 | 122.1 | 84.6 | 35097.9 | 6 | 1400 | 8 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Continued

(b) U.S. Customary Units – Continued

| Sheet thickness, in. | Creep stress, ksi | Creep exposure, hr | Creep strain, percent | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|---|
| Haynes 188 | | | | | | | | | |
| .020 | 15.1 | 50.3 | .663 | 138.5 | 71.8 | 31617.1 | 37 | 1400 | 8 |
| .020 | 15.1 | 50.3 | .454 | 143.0 | 73.7 | 32487.3 | 47 | 1400 | 8 |
| .020 | 10.0 | 1198.9 | .590 | 121.0 | 70.6 | 32922.4 | 10 | 1400 | 8 |
| .020 | 10.0 | 1198.9 | .574 | 129.8 | 70.3 | 33067.4 | 16 | 1400 | 8 |
| .020 | 7.5 | 2040.0 | .494 | 135.5 | 70.6 | 33067.4 | 15 | 1400 | 8 |
| .020 | 7.5 | 2040.0 | .553 | 139.5 | 73.5 | 34662.8 | 11 | 1400 | 8 |
| .020 | 4.9 | 3500.5 | .462 | 128.4 | 74.5 | 33937.6 | 9 | 1400 | 8 |
| .020 | 4.9 | 3500.5 | | 131.7 | 76.1 | 33937.6 | 6 | 1400 | 8 |
| .010 | 15.1 | 25.1 | .790 | 127.6 | 72.7 | 33792.6 | 32 | 1400 | 8 |
| .010 | 15.1 | 25.1 | .564 | 132.0 | 71.8 | 33212.5 | 42 | 1400 | 8 |
| .010 | 10.0 | 146.3 | .794 | 123.9 | 68.7 | 32632.3 | 31 | 1400 | 8 |
| .010 | 10.0 | 146.3 | .535 | 129.4 | 69.8 | 33647.6 | 38 | 1400 | 8 |
| .010 | 7.5 | 602.3 | .394 | 110.2 | 66.9 | 34807.8 | 12 | 1400 | 8 |
| .010 | 7.5 | 602.3 | .628 | 113.7 | 67.2 | 33357.5 | 13 | 1400 | 8 |
| .020 | 10.0 | .3 | 1.560 | 136.3 | 66.0 | 33067.4 | 42 | 1800 | 8 |
| .020 | 10.0 | .3 | .827 | 137.8 | 66.9 | 33357.5 | 46 | 1800 | 8 |
| .020 | 7.5 | 1.3 | | 139.2 | 64.8 | 33792.6 | 47 | 1800 | 8 |
| .020 | 7.5 | 1.3 | .424 | 137.5 | 64.7 | 33212.5 | 46 | 1800 | 8 |
| .020 | 4.9 | 19.3 | 1.653 | 133.4 | 61.6 | 33067.4 | 31 | 1800 | 8 |
| .020 | 4.9 | 19.3 | 4.134 | 128.5 | 60.8 | 32487.3 | 29 | 1800 | 8 |
| .020 | 3.0 | 50.2 | .535 | 134.2 | 60.2 | 32777.4 | 39 | 1800 | 8 |
| .020 | 3.0 | 50.2 | .361 | 136.3 | 61.6 | 33647.6 | 40 | 1800 | 8 |
| .010 | 7.5 | .9 | .880 | 131.4 | | 33647.6 | 50 | 1800 | 8 |
| .010 | 7.5 | .9 | .636 | 129.7 | 64.8 | 31907.2 | 38 | 1800 | 8 |
| .010 | 4.9 | 26.7 | .631 | 117.2 | 59.6 | 33502.5 | 19 | 1800 | 8 |
| .010 | 4.9 | 26.7 | .066 | 119.8 | 61.8 | 34807.8 | 20 | 1800 | 8 |
| .010 | 3.0 | 43.0 | .482 | 124.0 | 63.7 | 33067.4 | 19 | 1800 | 8 |
| .010 | 3.0 | 43.0 | .785 | 117.6 | 58.7 | 33502.5 | 18 | 1800 | 8 |
| .020 | 15.1 | 93.6 | .948 | 129.8 | 74.8 | 33647.6 | 26 | 1400 | 1 |
| .020 | 15.1 | 93.6 | .594 | 134.0 | 74.3 | 35097.9 | 33 | 1400 | 1 |
| .020 | 8.0 | 70.3 | .433 | 135.6 | 66.1 | 33937.6 | 32 | 1600 | 1 |
| .020 | 8.0 | 70.3 | .648 | 135.0 | 65.0 | 33502.5 | 30 | 1600 | 1 |
| .020 | 7.0 | 244.5 | .513 | 135.6 | 67.4 | 35678.0 | 18 | 1600 | 1 |
| .020 | 7.0 | 244.5 | .700 | 125.5 | 66.4 | 33212.5 | 13 | 1600 | 1 |
| .020 | 5.9 | 525.1 | .490 | 135.6 | 65.1 | 32922.4 | 13 | 1600 | 1 |
| .020 | 5.9 | 525.1 | .467 | 133.4 | 66.0 | 33937.6 | 10 | 1600 | 1 |
| .020 | 4.1 | 50.3 | .574 | 136.5 | 61.5 | 33647.6 | 25 | 1800 | 1 |
| .020 | 4.1 | 50.3 | .470 | 136.5 | 61.5 | 33647.6 | 38 | 1800 | 1 |
| .020 | 4.1 | 49.5 | .143 | 126.9 | 59.6 | 33647.6 | 27 | 1800 | 1 |
| .020 | 4.1 | 49.5 | .676 | 126.9 | 60.3 | 33647.6 | 26 | 1800 | 1 |
| .020 | 3.5 | 188.8 | .412 | 134.0 | 60.0 | 32632.3 | 24 | 1800 | 1 |
| .020 | 3.5 | 188.8 | .638 | 134.0 | 58.2 | 33067.4 | 31 | 1800 | 1 |
| .020 | 3.5 | 117.6 | .597 | 131.3 | 58.2 | 33647.6 | 25 | 1800 | 1 |
| .020 | 3.5 | 117.6 | .934 | 130.1 | 59.2 | 33647.6 | 29 | 1800 | 1 |
| .020 | 3.0 | 212.9 | .532 | 132.4 | 61.1 | 33647.6 | 28 | 1800 | 1 |
| .020 | 3.0 | 212.9 | .449 | 131.7 | 62.4 | 33067.4 | 26 | 1800 | 1 |
| .020 | 3.0 | 165.0 | .375 | 132.7 | 58.2 | 33212.5 | 24 | 1800 | 1 |
| .020 | 3.0 | 165.0 | 1.153 | 128.2 | 55.7 | 32777.4 | 28 | 1800 | 1 |

TABLE VII.- RESIDUAL MATERIAL PROPERTIES AFTER CREEP TESTS – Concluded

(b) U.S. Customary Units – Concluded

| Sheet thickness, in. | Creep stress, ksi | Creep exposure, hr | Creep strain, percent | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|---|
| TD NiCr | | | | | | | | | |
| .020 | 20.0 | 60.0 | | | | | | 1400 | 8 |
| .020 | 20.0 | 60.0 | .214 | 101.1 | 95.7 | 24510.5 | 2 | 1400 | 8 |
| .020 | 20.0 | 43.0 | .246 | 124.9 | 92.1 | 23640.3 | 9 | 1400 | 8 |
| .020 | 20.0 | 43.0 | .610 | 55.0 | | 22770.1 | 1 | 1400 | 8 |
| .020 | 17.5 | 1171.9 | | | | | | 1400 | 8 |
| .020 | 17.5 | 1171.9 | .174 | 119.7 | 90.6 | 23495.3 | 7 | 1400 | 8 |
| .020 | 17.5 | 31.1 | | | | | | 1400 | 8 |
| .020 | 17.5 | 31.1 | .055 | 135.6 | 88.9 | 23060.2 | 21 | 1400 | 8 |
| .020 | 15.1 | 5008.7 | .167 | 103.8 | 90.1 | 24365.5 | 5 | 1400 | 8 |
| .020 | 15.1 | 5008.7 | .264 | 123.9 | 89.3 | 24075.4 | 10 | 1400 | 8 |
| .020 | 10.0 | 3836.3 | .089 | 131.5 | 89.2 | 23495.3 | 14 | 1400 | 8 |
| .020 | 10.0 | 3836.3 | .068 | 131.1 | 87.0 | 23785.4 | 15 | 1400 | 8 |
| | | | | | | | | | |
| .010 | 20.0 | 26.4 | .590 | 48.7 | | 22480.1 | 2 | 1400 | 8 |
| .010 | 20.0 | 26.4 | .309 | 74.8 | | 22770.1 | 2 | 1400 | 8 |
| .010 | 17.5 | 546.5 | .243 | | | | | 1400 | 8 |
| .010 | 17.5 | | | | | | | 1400 | 8 |
| .010 | 15.1 | 1578.9 | .040 | 103.7 | 85.7 | 22190.0 | 2 | 1400 | 8 |
| .010 | 15.1 | 1578.9 | .044 | 89.5 | 85.4 | 22625.1 | 2 | 1400 | 8 |
| .010 | 10.0 | 2034.4 | .041 | 110.2 | 83.8 | 22625.1 | 6 | 1400 | 8 |
| .010 | 10.0 | 2034.4 | .036 | 109.4 | 84.8 | 22335.0 | 2 | 1400 | 8 |
| | | | | | | | | | |
| .020 | 20.0 | .0 | | 110.8 | 97.2 | 23350.3 | 2 | 1800 | 8 |
| .020 | 20.0 | .0 | | | | | | 1800 | 8 |
| .020 | 17.5 | .1 | | 90.6 | 89.3 | 23350.3 | 2 | 1800 | 8 |
| .020 | 17.5 | .1 | | | | | | 1800 | 8 |
| .020 | 15.1 | .2 | | 101.5 | 93.5 | 24220.4 | 3 | 1800 | 8 |
| .020 | 15.1 | .2 | | | | | | 1800 | 8 |
| .020 | 13.1 | .5 | .139 | 116.9 | 89.8 | 23495.3 | 7 | 1800 | 8 |
| .020 | 13.1 | .5 | | | | | | 1800 | 8 |
| .020 | 10.0 | 145.7 | .059 | 65.8 | | 23350.3 | 3 | 1800 | 8 |
| .020 | 10.0 | 145.7 | | | | | | 1800 | 8 |
| .020 | 9.0 | 3.4 | .025 | 109.4 | 90.4 | 23930.4 | 6 | 1800 | 8 |
| .020 | 9.0 | 3.4 | | | | | | 1800 | 8 |
| .020 | 8.0 | 1149.6 | .081 | 108.8 | 88.6 | 23640.3 | 6 | 1800 | 8 |
| .020 | 8.0 | 1149.6 | | | | | | 1800 | 8 |
| .020 | 7.5 | 2087.4 | .217 | 88.3 | | 24945.6 | 2 | 1800 | 8 |
| .020 | 7.5 | 2087.4 | | | | | | 1800 | 8 |
| .020 | 4.9 | 1491.3 | .006 | 123.1 | 90.8 | 24220.4 | 8 | 1800 | 8 |
| .020 | 4.9 | 1491.3 | .050 | 102.5 | 89.9 | 23350.3 | 4 | 1800 | 8 |
| .020 | 4.9 | 2660.0 | .043 | 133.3 | 96.3 | 24365.5 | 11 | 1800 | 8 |
| .020 | 4.9 | 2660.0 | | 116.8 | 90.8 | 23495.3 | 6 | 1800 | 8 |
| | | | | | | | | | |
| .010 | 15.1 | 3.3 | .276 | 63.4 | | 21899.9 | | 1800 | 8 |
| .010 | 15.1 | 3.3 | | | | | | 1800 | 8 |
| .010 | 10.0 | 282.5 | .128 | | | | | 1800 | 8 |
| .010 | 10.0 | 282.5 | | | | | | 1800 | 8 |
| | | | | | | | | | |
| .020 | 18.0 | 2.8 | .080 | 136.3 | 91.8 | 23350.3 | 13 | 1600 | 1 |
| .020 | 18.0 | 2.8 | | | | | | 1600 | 1 |
| .020 | 15.1 | 82.8 | .214 | 85.7 | | 23495.3 | 2 | 1600 | 1 |
| .020 | 15.1 | 82.8 | | | | | | 1600 | 1 |
| .020 | 12.0 | 1013.7 | .012 | 129.9 | 90.5 | 23640.3 | 10 | 1600 | 1 |
| .020 | 12.0 | 1013.7 | .115 | 105.6 | 89.6 | 23640.3 | 4 | 1600 | 1 |
| | | | | | | | | | |
| .020 | 14.1 | 14.2 | .090 | 121.3 | 92.1 | 23060.2 | 7 | 1800 | 1 |
| .020 | 14.1 | 14.2 | | | | | | 1800 | 1 |
| .020 | 12.0 | 16.4 | .081 | 122.6 | 89.1 | 23350.3 | 9 | 1800 | 1 |
| .020 | 12.0 | 16.4 | | | | | | 1800 | 1 |
| .020 | 11.0 | 49.3 | .028 | 127.2 | 87.7 | 23930.4 | 12 | 1800 | 1 |
| .020 | 11.0 | 49.3 | | | | | | 1800 | 1 |
| .020 | 10.0 | 310.3 | .048 | 110.9 | 37.0 | 22770.1 | 4 | 1800 | 1 |
| .020 | 10.0 | 310.3 | | | | | | 1800 | 1 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS

(a) SI Units

| Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m² | Yield strength, MN/m² | Modulus of elasticity, GN/m² | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m² |
|---|---|---|---|---|---|---|---|
| René 41 | | | | | | | |
| .508 | 50.0 | 1400.0 | 1130.0 | 216.0 | 21 | 1033 | .13 |
| .508 | 50.0 | 1420.0 | 1120.0 | 222.0 | 19 | 1033 | .13 |
| .508 | 100.0 | 1400.0 | 1100.0 | 220.0 | 15 | 1033 | .13 |
| .508 | 100.0 | 1400.0 | 1100.0 | 222.0 | 17 | 1033 | .13 |
| .508 | 200.0 | 1390.0 | 1080.0 | 220.0 | 14 | 1033 | .13 |
| .508 | 200.0 | 1390.0 | 1080.0 | 216.0 | 17 | 1033 | .13 |
| .508 | 502.0 | 1380.0 | 1070.0 | 222.0 | 12 | 1033 | .13 |
| .508 | 502.0 | 1380.0 | 1065.0 | 220.0 | 12 | 1033 | .13 |
| .508 | 1002.0 | 1340.0 | 1020.0 | 224.0 | 10 | 1033 | 1.07 |
| .508 | 1002.0 | 1300.0 | 993.0 | 223.0 | 7 | 1033 | 1.07 |
| .508 | 2000.0 | 1310.0 | 998.0 | 225.0 | 8 | 1033 | 1.07 |
| .508 | 2000.0 | 1260.0 | 969.0 | 222.0 | 6 | 1033 | 1.07 |
| .508 | 5000.0 | 1240.0 | 900.0 | 220.0 | 5 | 1033 | 1.07 |
| .508 | 5000.0 | 1240.0 | 880.0 | 215.0 | 5 | 1033 | 1.07 |
| .508 | 25.0 | 1161.0 | 748.0 | 219.0 | 23 | 1256 | .13 |
| .508 | 25.0 | 1143.0 | 742.0 | 221.0 | | 1256 | .13 |
| .508 | 50.0 | 1132.0 | 727.0 | 218.0 | | 1256 | .13 |
| .508 | 50.0 | 1120.0 | 732.0 | 222.0 | 23 | 1256 | .13 |
| .508 | 100.0 | 1076.0 | 689.0 | 218.0 | 22 | 1256 | .13 |
| .508 | 100.0 | 1056.0 | 687.0 | 229.0 | 23 | 1256 | .13 |
| .508 | 200.0 | 1009.0 | 656.0 | 218.0 | | 1256 | .13 |
| .508 | 200.0 | 995.0 | 636.0 | 222.0 | 21 | 1256 | .13 |
| .508 | 50.0 | 1148.0 | 750.0 | 219.0 | 21 | 1256 | 1.07 |
| .508 | 50.0 | 1128.0 | 742.0 | 229.0 | 23 | 1256 | 1.07 |
| .508 | 100.0 | 1064.0 | 690.0 | 215.0 | | 1256 | 1.07 |
| .508 | 100.0 | 1068.0 | 698.0 | 224.0 | 15 | 1256 | 1.07 |
| .508 | 200.0 | 1020.0 | 659.0 | 215.0 | 14 | 1256 | 1.07 |
| .508 | 200.0 | 1027.0 | 656.0 | 215.0 | 13 | 1256 | 1.07 |
| .508 | 500.0 | 835.0 | 607.0 | 199.0 | 14 | 1256 | 1.07 |
| .508 | 500.0 | 859.0 | 567.0 | 225.0 | 8 | 1256 | 1.07 |
| .508 | 1000.0 | 752.0 | 539.0 | 199.0 | 14 | 1256 | 1.07 |
| .508 | 1000.0 | 784.0 | 567.0 | 206.0 | 13 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Continued

| | Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m$^2$ | Yield strength, MN/m$^2$ | Modulus of elasticity, GN/m$^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m$^2$ |
|---|---|---|---|---|---|---|---|---|
| Hastelloy X | | | | | | | | |
| | .508 | 50.0 | 831.0 | 425.0 | 204.0 | 30 | 1033 | .13 |
| | .508 | 50.0 | 834.0 | 439.0 | 204.0 | 29 | 1033 | .13 |
| | .508 | 100.0 | 851.0 | 420.0 | 208.0 | 25 | 1033 | .13 |
| | .508 | 100.0 | 851.0 | 417.0 | 208.0 | 24 | 1033 | .13 |
| | .508 | 200.0 | 860.0 | 411.0 | 202.0 | 28 | 1033 | .13 |
| | .508 | 200.0 | 860.0 | 409.0 | 200.0 | 28 | 1033 | .13 |
| | .508 | 502.0 | 861.0 | 409.0 | 200.0 | 27 | 1033 | .13 |
| | .508 | 502.0 | 861.0 | 407.0 | 206.0 | 26 | 1033 | .13 |
| | | | | | | | | |
| | .508 | 1002.0 | 891.0 | 414.0 | 210.0 | 26 | 1033 | 1.07 |
| | .508 | 1002.0 | 876.0 | 403.0 | 217.0 | 24 | 1033 | 1.07 |
| | .508 | 2000.0 | 886.0 | 406.0 | 208.0 | 22 | 1033 | 1.07 |
| | .508 | 2000.0 | 895.0 | 417.0 | 210.0 | 23 | 1033 | 1.07 |
| | | | | | | | | |
| | .508 | 25.0 | 742.0 | 354.0 | 204.0 | 22 | 1256 | .13 |
| | .508 | 25.0 | 761.0 | 356.0 | 202.0 | 20 | 1256 | .13 |
| | .508 | 50.0 | 739.0 | 344.0 | 200.0 | 24 | 1256 | .13 |
| | .508 | 50.0 | 725.0 | 333.0 | 204.0 | 23 | 1256 | .13 |
| | .508 | 100.0 | 695.0 | 322.0 | 194.0 | 18 | 1256 | .13 |
| | .508 | 100.0 | 705.0 | 326.0 | 199.0 | 19 | 1256 | .13 |
| | .508 | 200.0 | 660.0 | 296.0 | 199.0 | 13 | 1256 | .13 |
| | .508 | 200.0 | 637.0 | 290.0 | 206.0 | | 1256 | .13 |
| | | | | | | | | |
| | .508 | 50.0 | 734.0 | 370.0 | 220.0 | 25 | 1256 | 1.07 |
| | .508 | 50.0 | 751.0 | 344.0 | 195.0 | 26 | 1256 | 1.07 |
| | .508 | 100.0 | 721.0 | 330.0 | 200.0 | 20 | 1256 | 1.07 |
| | .508 | 100.0 | 712.0 | 315.0 | 209.0 | 23 | 1256 | 1.07 |
| | .508 | 200.0 | 674.0 | 294.0 | 197.0 | 20 | 1256 | 1.07 |
| | .508 | 200.0 | 705.0 | 314.0 | 206.0 | | 1256 | 1.07 |
| | .508 | 500.0 | 575.0 | 267.0 | 203.0 | 15 | 1256 | 1.07 |
| | .508 | 500.0 | 624.0 | 305.0 | 198.0 | 13 | 1256 | 1.07 |
| | .508 | 1000.0 | 528.0 | 273.0 | 196.0 | | 1256 | 1.07 |
| | .508 | 1000.0 | 519.0 | 273.0 | 195.0 | | 1256 | 1.07 |
| | .508 | 2000.0 | 424.0 | 292.0 | 219.0 | 12 | 1256 | 1.07 |
| | .508 | 2000.0 | 425.0 | 265.0 | 196.0 | 10 | 1256 | 1.07 |
| | .508 | 3500.0 | 355.0 | 264.0 | 172.0 | 4 | 1256 | 1.07 |
| | .508 | 3500.0 | 369.0 | 254.0 | 180.0 | 4 | 1256 | 1.07 |
| | .508 | 5000.0 | 313.0 | 254.0 | 190.0 | 2 | 1256 | 1.07 |
| | .508 | 5000.0 | 268.0 | 228.0 | 164.0 | 1 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Continued

| Sheet thickness, mm | Exposure, hr | Tensile strength, $MN/m^2$ | Yield strength, $MN/m^2$ | Modulus of elasticity, $GN/m^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, $kN/m^2$ |
|---|---|---|---|---|---|---|---|
| Inconel 625 | | | | | | | |
| .508 | 50.0 | 975.0 | 515.0 | 216.0 | 43 | 1033 | .13 |
| .508 | 50.0 | 975.0 | 513.0 | 216.0 | 44 | 1033 | .13 |
| .508 | 100.0 | 1040.0 | 516.0 | 216.0 | 39 | 1033 | .13 |
| .508 | 100.0 | 1030.0 | 611.0 | 213.0 | 38 | 1033 | .13 |
| .508 | 200.0 | 1060.0 | 653.0 | 215.0 | 35 | 1033 | .13 |
| .508 | 200.0 | 1065.0 | 652.0 | 216.0 | 35 | 1033 | .13 |
| .508 | 502.0 | 1095.0 | 718.0 | 216.0 | 32 | 1033 | .13 |
| .508 | 502.0 | 1090.0 | 716.0 | 216.0 | 32 | 1033 | .13 |
| | | | | | | | |
| .508 | 1002.0 | 1110.0 | 743.0 | 220.0 | 29 | 1033 | 1.07 |
| .508 | 1002.0 | 1110.0 | 741.0 | 221.0 | 30 | 1033 | 1.07 |
| .508 | 2000.0 | 1110.0 | 740.0 | 219.0 | 26 | 1033 | 1.07 |
| .508 | 2000.0 | 1090.0 | 721.0 | 219.0 | 25 | 1033 | 1.07 |
| | | | | | | | |
| .508 | 25.0 | 923.0 | 432.0 | 212.0 | 35 | 1256 | .13 |
| .508 | 25.0 | 923.0 | 434.0 | 214.0 | 34 | 1256 | .13 |
| .508 | 50.0 | 908.0 | 416.0 | 216.0 | 34 | 1256 | .13 |
| .508 | 50.0 | 906.0 | 416.0 | 217.0 | 34 | 1256 | .13 |
| .508 | 100.0 | 890.0 | 391.0 | 219.0 | 34 | 1256 | .13 |
| .508 | 100.0 | 893.0 | 425.0 | 216.0 | 32 | 1256 | .13 |
| .508 | 200.0 | 843.0 | 423.0 | 212.0 | 39 | 1256 | .13 |
| .508 | 200.0 | 862.0 | 418.0 | 212.0 | 43 | 1256 | .13 |
| | | | | | | | |
| .508 | 50.0 | 896.0 | 408.0 | 216.0 | -0 | 1256 | 1.07 |
| .508 | 50.0 | 914.0 | 432.0 | 210.0 | | 1256 | 1.07 |
| .508 | 100.0 | 886.0 | 424.0 | 220.0 | | 1256 | 1.07 |
| .508 | 100.0 | 888.0 | 443.0 | 210.0 | 47 | 1256 | 1.07 |
| .508 | 200.0 | 865.0 | 413.0 | 211.0 | 47 | 1256 | 1.07 |
| .508 | 200.0 | 837.0 | 381.0 | 213.0 | 33 | 1256 | 1.07 |
| .508 | 500.0 | 785.0 | 362.0 | 193.0 | 42 | 1256 | 1.07 |
| .508 | 500.0 | 774.0 | 346.0 | 195.0 | 42 | 1256 | 1.07 |
| .508 | 1000.0 | 746.0 | 332.0 | 200.0 | 44 | 1256 | 1.07 |
| .508 | 1000.0 | 746.0 | 326.0 | 199.0 | 43 | 1256 | 1.07 |
| .508 | 2000.0 | 625.0 | 305.0 | 188.0 | 25 | 1256 | 1.07 |
| .508 | 2000.0 | 640.0 | 302.0 | 196.0 | 29 | 1256 | 1.07 |
| .508 | 3500.0 | 444.0 | 240.0 | 208.0 | 13 | 1256 | 1.07 |
| .508 | 3500.0 | 509.0 | 301.0 | 183.0 | 16 | 1256 | 1.07 |
| .508 | 5000.0 | 381.0 | 244.0 | 205.0 | 3 | 1256 | 1.07 |
| .508 | 5000.0 | 331.0 | 228.0 | 173.0 | 6 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Continued

| Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m$^2$ | Yield strength, MN/m$^2$ | Modulus of elasticity, GN/m$^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m$^2$ |
|---|---|---|---|---|---|---|---|
| Inconel 718 | | | | | | | |
| .508 | 50.0 | 1295.0 | 966.0 | 206.0 | 24 | 1033 | .13 |
| .508 | 50.0 | 1270.0 | 956.0 | 206.0 | 26 | 1033 | .13 |
| .508 | 100.0 | 1250.0 | 924.0 | 206.0 | 22 | 1033 | .13 |
| .508 | 100.0 | 1240.0 | 915.0 | 206.0 | 21 | 1033 | .13 |
| .508 | 200.0 | 1230.0 | 870.0 | 209.0 | 18 | 1033 | .13 |
| .508 | 200.0 | 1230.0 | 870.0 | 210.0 | 19 | 1033 | .13 |
| .508 | 502.0 | 1170.0 | 755.0 | 206.0 | 21 | 1033 | .13 |
| .508 | 502.0 | 1175.0 | 761.0 | 206.0 | 19 | 1033 | .13 |
| | | | | | | | |
| .508 | 1002.0 | 1100.0 | 683.0 | 210.0 | 20 | 1033 | 1.07 |
| .508 | 1002.0 | 1075.0 | 677.0 | 210.0 | 22 | 1033 | 1.07 |
| .508 | 2000.0 | 1055.0 | 679.0 | 209.0 | 17 | 1033 | 1.07 |
| .508 | 2000.0 | 1080.0 | 679.0 | 210.0 | 18 | 1033 | 1.07 |
| | | | | | | | |
| .508 | 25.0 | 1221.0 | 995.0 | 202.0 | 22 | 1256 | .13 |
| .508 | 25.0 | 1197.0 | 880.0 | 207.0 | 24 | 1256 | .13 |
| .508 | 50.0 | 1052.0 | 626.0 | 204.0 | 32 | 1256 | .13 |
| .508 | 50.0 | 1030.0 | 589.0 | 206.0 | | 1256 | .13 |
| .508 | 100.0 | 1040.0 | 668.0 | 197.0 | 28 | 1256 | .13 |
| .508 | 100.0 | 1011.0 | 610.0 | 195.0 | 31 | 1256 | .13 |
| .508 | 200.0 | 914.0 | 523.0 | 201.0 | 29 | 1256 | .13 |
| .508 | 200.0 | 956.0 | 591.0 | 197.0 | | 1256 | .13 |
| | | | | | | | |
| .508 | 50.0 | 1190.0 | 871.0 | 207.0 | | 1256 | 1.07 |
| .508 | 50.0 | 1173.0 | 865.0 | 208.0 | | 1256 | 1.07 |
| .508 | 100.0 | 1111.0 | 789.0 | 193.0 | 22 | 1256 | 1.07 |
| .508 | 100.0 | 1085.0 | 715.0 | 204.0 | 25 | 1256 | 1.07 |
| .508 | 200.0 | 950.0 | 596.0 | 193.0 | 28 | 1256 | 1.07 |
| .508 | 200.0 | 964.0 | 618.0 | 194.0 | 21 | 1256 | 1.07 |
| .508 | 500.0 | 880.0 | 584.0 | 197.0 | 24 | 1256 | 1.07 |
| .508 | 500.0 | 891.0 | 606.0 | 186.0 | 20 | 1256 | 1.07 |
| .508 | 1000.0 | 753.0 | 564.0 | 190.0 | 18 | 1256 | 1.07 |
| .508 | 1000.0 | 740.0 | 558.0 | 187.0 | 15 | 1256 | 1.07 |
| .508 | 2000.0 | 501.0 | 326.0 | 186.0 | | 1256 | 1.07 |
| .508 | 2000.0 | 446.0 | 341.0 | 168.0 | 12 | 1256 | 1.07 |
| .508 | 3500.0 | 385.0 | 264.0 | 172.0 | 6 | 1256 | 1.07 |
| .508 | 3500.0 | 365.0 | 259.0 | 170.0 | 6 | 1256 | 1.07 |
| .508 | 5000.0 | 261.0 | 190.0 | 150.0 | 4 | 1256 | 1.07 |
| .508 | 5000.0 | 270.0 | 202.0 | 148.0 | 4 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Continued

| | Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m$^2$ | Yield strength, MN/m$^2$ | Modulus of elasticity, GN/m$^2$ | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m$^2$ |
|---|---|---|---|---|---|---|---|---|
| Haynes 25 | | | | | | | | |
| | .508 | 50.0 | 931.0 | 499.0 | 243.0 | 37 | 1033 | .13 |
| | .508 | 50.0 | 928.0 | 482.0 | 247.0 | 36 | 1033 | .13 |
| | .508 | 100.0 | 906.0 | 492.0 | 241.0 | 31 | 1033 | .13 |
| | .508 | 100.0 | 886.0 | 485.0 | 240.0 | 30 | 1033 | .13 |
| | .508 | 200.0 | 870.0 | 488.0 | 245.0 | 26 | 1033 | .13 |
| | .508 | 200.0 | 917.0 | 492.0 | 246.0 | 33 | 1033 | .13 |
| | .508 | 502.0 | 895.0 | 504.0 | 244.0 | 28 | 1033 | .13 |
| | .508 | 502.0 | 875.0 | 507.0 | 242.0 | 25 | 1033 | .13 |
| | | | | | | | | |
| | .508 | 1002.0 | 880.0 | 494.0 | 248.0 | 23 | 1033 | 1.07 |
| | .508 | 1002.0 | 878.0 | 480.0 | 246.0 | 24 | 1033 | 1.07 |
| | .508 | 2000.0 | 869.0 | 494.0 | 245.0 | | 1033 | 1.07 |
| | .508 | 2000.0 | 872.0 | 520.0 | 251.0 | 20 | 1033 | 1.07 |
| | .508 | 5000.0 | 874.0 | 525.0 | 228.0 | 11 | 1033 | 1.07 |
| | .508 | 5000.0 | 836.0 | 505.0 | 219.0 | 7 | 1033 | 1.07 |
| | | | | | | | | |
| | .508 | 25.0 | 918.0 | 467.0 | 242.0 | 40 | 1256 | .13 |
| | .508 | 25.0 | 909.0 | 461.0 | 242.0 | 41 | 1256 | .13 |
| | .508 | 50.0 | 870.0 | 466.0 | 238.0 | 30 | 1256 | .13 |
| | .508 | 50.0 | 889.0 | 454.0 | 244.0 | 30 | 1256 | .13 |
| | .508 | 100.0 | 856.0 | 447.0 | 237.0 | 20 | 1256 | .13 |
| | .508 | 100.0 | 863.0 | 452.0 | 256.0 | 20 | 1256 | .13 |
| | .508 | 200.0 | 835.0 | 442.0 | 238.0 | 20 | 1256 | .13 |
| | .508 | 200.0 | 825.0 | 436.0 | 236.0 | | 1256 | .13 |
| | | | | | | | | |
| | .508 | 50.0 | 891.0 | 456.0 | 241.0 | 33 | 1256 | 1.07 |
| | .508 | 50.0 | 885.0 | 456.0 | 243.0 | 33 | 1256 | 1.07 |
| | .508 | 100.0 | 863.0 | 435.0 | 247.0 | 27 | 1256 | 1.07 |
| | .508 | 100.0 | 811.0 | 426.0 | 245.0 | 21 | 1256 | 1.07 |
| | .508 | 200.0 | 830.0 | 430.0 | 242.0 | 17 | 1256 | 1.07 |
| | .508 | 200.0 | 880.0 | 438.0 | 242.0 | 15 | 1256 | 1.07 |
| | .508 | 500.0 | 776.0 | 426.0 | 230.0 | 10 | 1256 | 1.07 |
| | .508 | 500.0 | 770.0 | 421.0 | 234.0 | 11 | 1256 | 1.07 |
| | .508 | 1000.0 | 736.0 | 428.0 | 228.0 | 16 | 1256 | 1.07 |
| | .508 | 1000.0 | 724.0 | 423.0 | 231.0 | 16 | 1256 | 1.07 |
| | .508 | 2000.0 | 610.0 | 393.0 | 224.0 | 10 | 1256 | 1.07 |
| | .508 | 2000.0 | 628.0 | 416.0 | 213.0 | | 1256 | 1.07 |
| | .508 | 3500.0 | 447.0 | 357.0 | 206.0 | | 1256 | 1.07 |
| | .508 | 3500.0 | 475.0 | 369.0 | 220.0 | 4 | 1256 | 1.07 |
| | .508 | 5000.0 | 298.0 | 289.0 | 182.0 | 2 | 1256 | 1.07 |
| | .508 | 5000.0 | 358.0 | 281.0 | 202.0 | 4 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Continued

| | Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m² | Yield strength, MN/m² | Modulus of elasticity, GN/m² | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m² |
|---|---|---|---|---|---|---|---|---|
| Haynes 188 | | | | | | | | |
| | .508 | 50.0 | 976.0 | 486.0 | 242.0 | 48 | 1033 | .13 |
| | .508 | 50.0 | 976.0 | 484.0 | 230.0 | 48 | 1033 | .13 |
| | .508 | 100.0 | 960.0 | 482.0 | 234.0 | 35 | 1033 | .13 |
| | .508 | 100.0 | 979.0 | 484.0 | 230.0 | 46 | 1033 | .13 |
| | .508 | 200.0 | 974.0 | 488.0 | 233.0 | 36 | 1033 | .13 |
| | .508 | 200.0 | 974.0 | 481.0 | 236.0 | 39 | 1033 | .13 |
| | .508 | 502.0 | 964.0 | 485.0 | 243.0 | 32 | 1033 | .13 |
| | .508 | 502.0 | 964.0 | 485.0 | 235.0 | 32 | 1033 | .13 |
| | | | | | | | | |
| | .508 | 1002.0 | 910.0 | 471.0 | 237.0 | 17 | 1033 | 1.07 |
| | .508 | 1002.0 | 874.0 | 471.0 | 241.0 | 16 | 1033 | 1.07 |
| | .508 | 2000.0 | 978.0 | 473.0 | 237.0 | 21 | 1033 | 1.07 |
| | .508 | 2000.0 | 970.0 | 475.0 | 239.0 | 21 | 1033 | 1.07 |
| | .508 | 5000.0 | 1030.0 | 505.0 | 234.0 | 15 | 1033 | 1.07 |
| | .508 | 5000.0 | 1045.0 | 493.0 | 219.0 | 17 | 1033 | 1.07 |
| | | | | | | | | |
| | .508 | 25.0 | 946.0 | 426.0 | 232.0 | 32 | 1255 | .13 |
| | .508 | 25.0 | 940.0 | 416.0 | 224.0 | 32 | 1255 | .13 |
| | .508 | 50.0 | 946.0 | 423.0 | 229.0 | 37 | 1256 | .13 |
| | .508 | 50.0 | 943.0 | 421.0 | 234.0 | 38 | 1256 | .13 |
| | .508 | 100.0 | 922.0 | 402.0 | 228.0 | 31 | 1256 | .13 |
| | .508 | 100.0 | 930.0 | 412.0 | 258.0 | 32 | 1256 | .13 |
| | .508 | 200.0 | 871.0 | 431.0 | 244.0 | 28 | 1255 | .13 |
| | .508 | 200.0 | 894.0 | 385.0 | 235.0 | 28 | 1256 | .13 |
| | | | | | | | | |
| | .508 | 50.0 | 901.0 | 443.0 | 241.0 | 38 | 1256 | 1.07 |
| | .508 | 50.0 | 905.0 | 440.0 | 243.0 | | 1256 | 1.07 |
| | .508 | 100.0 | 845.0 | 437.0 | 241.0 | 23 | 1256 | 1.07 |
| | .508 | 200.0 | 822.0 | 426.0 | 234.0 | 20 | 1256 | 1.07 |
| | .508 | 200.0 | 830.0 | 426.0 | 235.0 | 20 | 1256 | 1.07 |
| | .508 | 500.0 | 799.0 | 415.0 | 235.0 | 12 | 1256 | 1.07 |
| | .508 | 500.0 | 791.0 | 416.0 | 236.0 | 16 | 1256 | 1.07 |
| | .508 | 1000.0 | 731.0 | 411.0 | 229.0 | 16 | 1256 | 1.07 |
| | .508 | 1000.0 | 760.0 | 417.0 | 226.0 | 15 | 1256 | 1.07 |
| | .508 | 2000.0 | 610.0 | 409.0 | 216.0 | 10 | 1256 | 1.07 |
| | .508 | 2000.0 | 665.0 | 409.0 | 212.0 | 14 | 1256 | 1.07 |
| | .508 | 3500.0 | 433.0 | 343.0 | 198.0 | | 1256 | 1.07 |
| | .508 | 3500.0 | 487.0 | 374.0 | 216.0 | | 1256 | 1.07 |
| | .508 | 5000.0 | 342.0 | 384.0 | 175.0 | 2 | 1256 | 1.07 |
| | .508 | 5000.0 | 367.0 | 292.0 | | 3 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(a) SI Units – Concluded

| Sheet thickness, mm | Exposure, hr | Tensile strength, MN/m² | Yield strength, MN/m² | Modulus of elasticity, GN/m² | Elongation in 2.54 cm, percent | Temperature, K | Pressure, kN/m² |
|---|---|---|---|---|---|---|---|
| TD NiCr | | | | | | | |
| .508 | 50.0 | 948.0 | 640.0 | 165.0 | 20 | 1033 | .13 |
| .508 | 50.0 | 940.0 | 647.0 | 174.0 | 17 | 1033 | .13 |
| .508 | 100.0 | 971.0 | 658.0 | 178.0 | 18 | 1033 | .13 |
| .508 | 100.0 | 920.0 | 619.0 | 162.0 | 14 | 1033 | .13 |
| .508 | 200.0 | 960.0 | 649.0 | 170.0 | 18 | 1033 | .13 |
| .508 | 200.0 | 932.0 | 631.0 | 171.0 | 19 | 1033 | .13 |
| .508 | 502.0 | 939.0 | 620.0 | 168.0 | 18 | 1033 | .13 |
| .508 | 502.0 | 935.0 | 620.0 | 168.0 | 21 | 1033 | .13 |
| | | | | | | | |
| .508 | 1002.0 | 884.0 | 627.0 | 171.0 | 12 | 1033 | 1.07 |
| .508 | 1002.0 | 938.0 | 621.0 | 171.0 | 18 | 1033 | 1.07 |
| .508 | 2000.0 | 948.0 | 634.0 | 168.0 | 18 | 1033 | 1.07 |
| .508 | 2000.0 | 960.0 | 642.0 | 172.0 | 19 | 1033 | 1.07 |
| .508 | 5000.0 | 932.0 | 605.0 | 166.0 | 18 | 1033 | 1.07 |
| .508 | 5000.0 | 936.0 | 594.0 | 167.0 | 15 | 1033 | 1.07 |
| | | | | | | | |
| .508 | 50.0 | 887.0 | 614.0 | 162.0 | 13 | 1256 | .13 |
| .508 | 100.0 | 951.0 | 635.0 | 162.0 | 18 | 1256 | .13 |
| .508 | 200.0 | 954.0 | 632.0 | 163.0 | 19 | 1256 | .13 |
| | | | | | | | |
| .508 | 1000.0 | 941.0 | 619.0 | 155.0 | 19 | 1256 | 1.07 |
| .508 | 2000.0 | 995.0 | 642.0 | 162.0 | 17 | 1256 | 1.07 |
| .508 | 5000.0 | 836.0 | | 171.0 | 10 | 1256 | 1.07 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units

| Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|
| René 41 | | | | | | | |
| .020 | 50.0 | 203.0 | 163.9 | 31327.0 | 21 | 1400 | 1 |
| .020 | 50.0 | 205.9 | 162.4 | 32197.2 | 19 | 1400 | 1 |
| .020 | 100.0 | 203.0 | 159.5 | 31907.2 | 15 | 1400 | 1 |
| .020 | 100.0 | 203.0 | 159.5 | 32197.2 | 17 | 1400 | 1 |
| .020 | 200.0 | 201.6 | 156.6 | 31907.2 | 14 | 1400 | 1 |
| .020 | 200.0 | 201.6 | 155.6 | 31327.0 | 17 | 1400 | 1 |
| .020 | 502.0 | 200.1 | 155.2 | 32197.2 | 12 | 1400 | 1 |
| .020 | 502.0 | 200.1 | 154.5 | 31907.2 | 12 | 1400 | 1 |
| .020 | 1002.0 | 194.3 | 147.9 | 32487.3 | 10 | 1400 | 8 |
| .020 | 1002.0 | 188.5 | 144.0 | 32342.3 | 7 | 1400 | 8 |
| .020 | 2000.0 | 190.0 | 144.7 | 32632.3 | 8 | 1400 | 8 |
| .020 | 2000.0 | 182.7 | 140.5 | 32197.2 | 6 | 1400 | 8 |
| .020 | 5000.0 | 179.8 | 130.5 | 31907.2 | 5 | 1400 | 8 |
| .020 | 5000.0 | 179.8 | 127.6 | 31182.0 | 5 | 1400 | 8 |
| .020 | 25.0 | 168.4 | 108.5 | 31762.1 | 23 | 1800 | 1 |
| .020 | 25.0 | 165.8 | 107.6 | 32052.2 | | 1800 | 1 |
| .020 | 50.0 | 164.2 | 105.4 | 31617.1 | | 1800 | 1 |
| .020 | 50.0 | 162.4 | 106.2 | 32197.2 | 23 | 1800 | 1 |
| .020 | 100.0 | 156.1 | 99.9 | 31617.1 | 22 | 1800 | 1 |
| .020 | 100.0 | 153.4 | 99.6 | 33212.5 | 23 | 1800 | 1 |
| .020 | 200.0 | 146.3 | 95.1 | 31617.1 | | 1800 | 1 |
| .020 | 200.0 | 144.3 | 92.2 | 32197.2 | 21 | 1800 | 1 |
| .020 | 50.0 | 166.5 | 108.8 | 31762.1 | 21 | 1800 | 8 |
| .020 | 50.0 | 163.6 | 107.6 | 33212.5 | 23 | 1800 | 8 |
| .020 | 100.0 | 154.3 | 100.1 | 31182.0 | | 1800 | 8 |
| .020 | 100.0 | 154.9 | 101.2 | 32487.3 | 15 | 1800 | 8 |
| .020 | 200.0 | 147.9 | 95.6 | 31182.0 | 14 | 1800 | 8 |
| .020 | 200.0 | 148.9 | 95.1 | 31182.0 | 13 | 1800 | 8 |
| .020 | 500.0 | 121.1 | 88.0 | 28861.5 | 14 | 1800 | 8 |
| .020 | 500.0 | 124.6 | 82.2 | 32632.3 | 8 | 1800 | 8 |
| .020 | 1000.0 | 109.1 | 78.2 | 28861.5 | 14 | 1800 | 8 |
| .020 | 1000.0 | 113.7 | 82.2 | 29876.7 | 13 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units – Continued

| | Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|
| Hastelloy X | | | | | | | | |
| | .020 | 50.0 | 120.5 | 61.6 | 29586.7 | 30 | 1400 | 1 |
| | .020 | 50.0 | 121.0 | 63.7 | 29586.7 | 29 | 1400 | 1 |
| | .020 | 100.0 | 123.4 | 60.9 | 30166.8 | 25 | 1400 | 1 |
| | .020 | 100.0 | 123.4 | 60.5 | 30166.8 | 24 | 1400 | 1 |
| | .020 | 200.0 | 124.7 | 59.6 | 29296.6 | 28 | 1400 | 1 |
| | .020 | 200.0 | 124.7 | 59.3 | 29006.5 | 28 | 1400 | 1 |
| | .020 | 502.0 | 124.9 | 59.3 | 29006.5 | 27 | 1400 | 1 |
| | .020 | 502.0 | 124.9 | 59.0 | 29876.7 | 26 | 1400 | 1 |
| | .020 | 1002.0 | 129.2 | 60.0 | 30456.9 | 26 | 1400 | 8 |
| | .020 | 1002.0 | 127.0 | 58.4 | 31472.1 | 24 | 1400 | 8 |
| | .020 | 2000.0 | 128.5 | 58.9 | 30166.8 | 22 | 1400 | 8 |
| | .020 | 2000.0 | 129.8 | 60.5 | 30456.9 | 23 | 1400 | 8 |
| | .020 | 25.0 | 107.6 | 51.3 | 29586.7 | 22 | 1800 | 1 |
| | .020 | 25.0 | 110.4 | 51.6 | 29296.6 | 20 | 1800 | 1 |
| | .020 | 50.0 | 107.2 | 49.9 | 29006.5 | 24 | 1800 | 1 |
| | .020 | 50.0 | 105.1 | 48.3 | 29586.7 | 23 | 1800 | 1 |
| | .020 | 100.0 | 100.8 | 46.7 | 28136.3 | 18 | 1800 | 1 |
| | .020 | 100.0 | 102.2 | 47.3 | 28861.5 | 19 | 1800 | 1 |
| | .020 | 200.0 | 95.7 | 42.9 | 28861.5 | 13 | 1800 | 1 |
| | .020 | 200.0 | 92.4 | 42.1 | 29876.7 | | 1800 | 1 |
| | .020 | 50.0 | 106.5 | 53.7 | 31907.2 | 25 | 1800 | 8 |
| | .020 | 50.0 | 108.9 | 49.9 | 28281.4 | 26 | 1800 | 8 |
| | .020 | 100.0 | 104.6 | 47.9 | 29006.5 | 20 | 1800 | 8 |
| | .020 | 100.0 | 103.3 | 45.7 | 30311.8 | 23 | 1800 | 8 |
| | .020 | 200.0 | 97.8 | 42.6 | 28571.4 | 20 | 1800 | 8 |
| | .020 | 200.0 | 102.2 | 45.5 | 29876.7 | | 1800 | 8 |
| | .020 | 500.0 | 83.4 | 38.7 | 29441.6 | 15 | 1800 | 8 |
| | .020 | 500.0 | 90.5 | 44.2 | 28716.5 | 13 | 1800 | 8 |
| | .020 | 1000.0 | 76.6 | 39.6 | 28426.4 | | 1800 | 8 |
| | .020 | 1000.0 | 75.3 | 39.6 | 28281.4 | | 1800 | 8 |
| | .020 | 2000.0 | 61.5 | 42.3 | 31762.1 | 12 | 1800 | 8 |
| | .020 | 2000.0 | 61.8 | 38.4 | 28426.4 | 10 | 1800 | 8 |
| | .020 | 3500.0 | 51.5 | 38.3 | 24945.6 | 4 | 1800 | 8 |
| | .020 | 3500.0 | 53.5 | 36.8 | 26976.1 | 4 | 1800 | 8 |
| | .020 | 5000.0 | 45.4 | 36.8 | 27556.2 | 2 | 1800 | 8 |
| | .020 | 5000.0 | 38.9 | 33.1 | 23785.4 | 1 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units – Continued

| | Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|
| Inconel 625 | | | | | | | | |
| | .020 | 50.0 | 141.4 | 74.7 | 31327.0 | 43 | 1400 | 1 |
| | .020 | 50.0 | 141.4 | 74.4 | 31327.0 | 44 | 1400 | 1 |
| | .020 | 100.0 | 150.8 | 89.3 | 31327.0 | 39 | 1400 | 1 |
| | .020 | 100.0 | 149.4 | 88.6 | 30892.0 | 38 | 1400 | 1 |
| | .020 | 200.0 | 153.7 | 94.7 | 31182.0 | 35 | 1400 | 1 |
| | .020 | 200.0 | 154.5 | 94.6 | 31327.0 | 35 | 1400 | 1 |
| | .020 | 502.0 | 158.8 | 104.1 | 31327.0 | 32 | 1400 | 1 |
| | .020 | 502.0 | 158.1 | 103.8 | 31327.0 | 32 | 1400 | 1 |
| | .020 | 1002.0 | 161.0 | 107.8 | 31907.2 | 29 | 1400 | 8 |
| | .020 | 1002.0 | 161.0 | 107.5 | 32052.2 | 30 | 1400 | 8 |
| | .020 | 2000.0 | 161.0 | 107.3 | 31762.1 | 26 | 1400 | 8 |
| | .020 | 2000.0 | 158.1 | 104.6 | 31762.1 | 25 | 1400 | 8 |
| | .020 | 25.0 | 133.9 | 62.7 | 30746.9 | 35 | 1800 | 1 |
| | .020 | 25.0 | 133.9 | 62.9 | 31037.0 | 34 | 1800 | 1 |
| | .020 | 50.0 | 131.7 | 60.3 | 31327.0 | 34 | 1800 | 1 |
| | .020 | 50.0 | 131.4 | 60.3 | 31472.1 | 34 | 1800 | 1 |
| | .020 | 100.0 | 129.1 | 56.7 | 31762.1 | 34 | 1800 | 1 |
| | .020 | 100.0 | 129.5 | 61.6 | 31327.0 | 32 | 1800 | 1 |
| | .020 | 200.0 | 122.3 | 61.3 | 30746.9 | 39 | 1800 | 1 |
| | .020 | 200.0 | 125.0 | 60.6 | 30746.9 | 43 | 1800 | 1 |
| | .020 | 50.0 | 129.9 | 59.2 | 31327.0 | | 1800 | 8 |
| | .020 | 50.0 | 132.6 | 62.7 | 30456.9 | | 1800 | 8 |
| | .020 | 100.0 | 128.5 | 61.5 | 31907.2 | | 1800 | 8 |
| | .020 | 100.0 | 128.8 | 64.2 | 30456.9 | 47 | 1800 | 8 |
| | .020 | 200.0 | 125.5 | 59.9 | 30601.9 | 47 | 1800 | 8 |
| | .020 | 200.0 | 121.4 | 55.3 | 30892.0 | 33 | 1800 | 8 |
| | .020 | 500.0 | 113.9 | 52.5 | 27991.3 | 42 | 1800 | 8 |
| | .020 | 500.0 | 112.3 | 50.2 | 28281.4 | 42 | 1800 | 8 |
| | .020 | 1000.0 | 108.2 | 48.2 | 29006.5 | 44 | 1800 | 8 |
| | .020 | 1000.0 | 108.2 | 47.3 | 28861.5 | 43 | 1800 | 8 |
| | .020 | 2000.0 | 90.6 | 44.2 | 27266.1 | 25 | 1800 | 8 |
| | .020 | 2000.0 | 92.8 | 43.8 | 28426.4 | 29 | 1800 | 8 |
| | .020 | 3500.0 | 64.4 | 34.8 | 30166.8 | 13 | 1800 | 8 |
| | .020 | 3500.0 | 73.8 | 43.7 | 26541.0 | 16 | 1800 | 8 |
| | .020 | 5000.0 | 55.3 | 35.4 | 29731.7 | 3 | 1800 | 8 |
| | .020 | 5000.0 | 48.0 | 33.1 | 25090.6 | 6 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units – Continued

| | Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|
| Inconel 718 | | | | | | | | |
| | .020 | 50.0 | 187.8 | 140.1 | 29876.7 | 24 | 1400 | 1 |
| | .020 | 50.0 | 184.2 | 138.7 | 29876.7 | 26 | 1400 | 1 |
| | .020 | 100.0 | 181.3 | 134.0 | 29876.7 | 22 | 1400 | 1 |
| | .020 | 100.0 | 179.8 | 132.7 | 29876.7 | 21 | 1400 | 1 |
| | .020 | 200.0 | 178.4 | 126.2 | 30311.8 | 18 | 1400 | 1 |
| | .020 | 200.0 | 178.4 | 126.2 | 30456.9 | 19 | 1400 | 1 |
| | .020 | 502.0 | 169.7 | 109.5 | 29876.7 | 21 | 1400 | 1 |
| | .020 | 502.0 | 170.4 | 110.4 | 29876.7 | 19 | 1400 | 1 |
| | .020 | 1002.0 | 159.5 | 99.1 | 30456.9 | 20 | 1400 | 8 |
| | .020 | 1002.0 | 155.9 | 98.2 | 30456.9 | 22 | 1400 | 8 |
| | .020 | 2000.0 | 153.0 | 98.5 | 30311.8 | 17 | 1400 | 8 |
| | .020 | 2000.0 | 156.6 | 98.5 | 30456.9 | 18 | 1400 | 8 |
| | .020 | 25.0 | 177.1 | 144.3 | 29296.6 | 22 | 1800 | 1 |
| | .020 | 25.0 | 173.6 | 127.6 | 30021.8 | 24 | 1800 | 1 |
| | .020 | 50.0 | 152.6 | 90.8 | 29586.7 | 32 | 1800 | 1 |
| | .020 | 50.0 | 149.4 | 85.4 | 29876.7 | | 1800 | 1 |
| | .020 | 100.0 | 150.8 | 96.9 | 28571.4 | 28 | 1800 | 1 |
| | .020 | 100.0 | 146.6 | 88.5 | 28281.4 | 31 | 1800 | 1 |
| | .020 | 200.0 | 132.6 | 75.9 | 29151.6 | 29 | 1800 | 1 |
| | .020 | 200.0 | 138.7 | 85.7 | 28571.4 | | 1800 | 1 |
| | .020 | 50.0 | 172.6 | 126.3 | 30021.8 | | 1800 | 8 |
| | .020 | 50.0 | 170.1 | 125.5 | 30166.8 | | 1800 | 8 |
| | .020 | 100.0 | 161.1 | 114.4 | 27991.3 | 22 | 1800 | 8 |
| | .020 | 100.0 | 157.4 | 103.7 | 29586.7 | 25 | 1800 | 8 |
| | .020 | 200.0 | 137.8 | 86.4 | 27991.3 | 28 | 1800 | 8 |
| | .020 | 200.0 | 139.8 | 89.6 | 28136.3 | 21 | 1800 | 8 |
| | .020 | 500.0 | 127.6 | 84.7 | 28571.4 | 24 | 1800 | 8 |
| | .020 | 500.0 | 129.2 | 87.9 | 26976.1 | 20 | 1800 | 8 |
| | .020 | 1000.0 | 110.7 | 81.8 | 27556.2 | 18 | 1800 | 8 |
| | .020 | 1000.0 | 107.3 | 80.9 | 27121.1 | 15 | 1800 | 8 |
| | .020 | 2000.0 | 72.7 | 47.3 | 26976.1 | | 1800 | 8 |
| | .020 | 2000.0 | 64.7 | 49.5 | 24365.5 | 12 | 1800 | 8 |
| | .020 | 3500.0 | 55.8 | 38.3 | 24945.6 | 6 | 1800 | 8 |
| | .020 | 3500.0 | 52.9 | 37.6 | 24655.5 | 6 | 1800 | 8 |
| | .020 | 5000.0 | 37.9 | 27.6 | 21754.9 | 4 | 1800 | 8 |
| | .020 | 5000.0 | 39.2 | 29.3 | 21464.8 | 4 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units – Continued

| | Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|
| Haynes 25 | | | | | | | | |
| | .020 | 50.0 | 135.0 | 72.4 | 35242.9 | 37 | 1400 | 1 |
| | .020 | 50.0 | 134.6 | 69.9 | 35823.1 | 36 | 1400 | 1 |
| | .020 | 100.0 | 131.4 | 71.4 | 34952.9 | 31 | 1400 | 1 |
| | .020 | 100.0 | 128.5 | 70.3 | 34807.8 | 30 | 1400 | 1 |
| | .020 | 200.0 | 126.2 | 70.8 | 35533.0 | 26 | 1400 | 1 |
| | .020 | 200.0 | 133.0 | 71.4 | 35678.0 | 33 | 1400 | 1 |
| | .020 | 502.0 | 129.8 | 73.1 | 35388.0 | 28 | 1400 | 1 |
| | .020 | 502.0 | 126.9 | 73.5 | 35097.9 | 25 | 1400 | 1 |
| | | | | | | | | |
| | .020 | 1002.0 | 127.6 | 71.6 | 35968.1 | 23 | 1400 | 8 |
| | .020 | 1002.0 | 127.3 | 69.6 | 35678.0 | 24 | 1400 | 8 |
| | .020 | 2000.0 | 126.0 | 71.6 | 35533.0 | | 1400 | 8 |
| | .020 | 2000.0 | 126.5 | 75.4 | 36403.2 | 20 | 1400 | 8 |
| | .020 | 5000.0 | 126.8 | 76.1 | 33067.4 | 11 | 1400 | 8 |
| | .020 | 5000.0 | 121.2 | 73.2 | 31762.1 | 7 | 1400 | 8 |
| | | | | | | | | |
| | .020 | 25.0 | 133.1 | 67.7 | 35097.9 | 40 | 1800 | 1 |
| | .020 | 25.0 | 131.8 | 66.9 | 35097.9 | 41 | 1800 | 1 |
| | .020 | 50.0 | 126.2 | 67.6 | 34517.8 | 30 | 1800 | 1 |
| | .020 | 50.0 | 128.9 | 65.8 | 35388.0 | 30 | 1800 | 1 |
| | .020 | 100.0 | 124.1 | 64.8 | 34372.7 | 20 | 1800 | 1 |
| | .020 | 100.0 | 125.2 | 65.6 | 37128.4 | 20 | 1800 | 1 |
| | .020 | 200.0 | 121.1 | 64.1 | 34517.8 | 20 | 1800 | 1 |
| | .020 | 200.0 | 119.7 | 63.2 | 34227.7 | | 1800 | 1 |
| | | | | | | | | |
| | .020 | 50.0 | 129.2 | 66.1 | 34952.9 | 33 | 1800 | 8 |
| | .020 | 50.0 | 128.4 | 66.1 | 35242.9 | 33 | 1800 | 8 |
| | .020 | 100.0 | 125.2 | 63.1 | 35823.1 | 27 | 1800 | 8 |
| | .020 | 100.0 | 117.6 | 61.8 | 35533.0 | 21 | 1800 | 8 |
| | .020 | 200.0 | 120.4 | 62.4 | 35097.9 | 17 | 1800 | 8 |
| | .020 | 200.0 | 127.6 | 63.5 | 35097.9 | 15 | 1800 | 8 |
| | .020 | 500.0 | 112.5 | 61.8 | 33357.5 | 10 | 1800 | 8 |
| | .020 | 500.0 | 111.7 | 61.1 | 33937.6 | 11 | 1800 | 8 |
| | .020 | 1000.0 | 106.7 | 62.1 | 33067.4 | 16 | 1800 | 8 |
| | .020 | 1000.0 | 105.0 | 61.3 | 33502.5 | 16 | 1800 | 8 |
| | .020 | 2000.0 | 88.5 | 57.0 | 32487.3 | 10 | 1800 | 8 |
| | .020 | 2000.0 | 91.1 | 60.3 | 30892.0 | | 1800 | 8 |
| | .020 | 3500.0 | 64.8 | 51.8 | 29876.7 | | 1800 | 8 |
| | .020 | 3500.0 | 68.9 | 53.5 | 31907.2 | 4 | 1800 | 8 |
| | .020 | 5000.0 | 43.2 | 41.9 | 26395.9 | 2 | 1800 | 8 |
| | .020 | 5000.0 | 51.9 | 40.8 | 29296.6 | 4 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Continued

(b) U.S. Customary Units – Continued

| | Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|---|
| Haynes 188 | | | | | | | | |
| | .020 | 50.0 | 141.6 | 70.5 | 35097.9 | 48 | 1400 | 1 |
| | .020 | 50.0 | 141.6 | 70.2 | 33357.5 | 48 | 1400 | 1 |
| | .020 | 100.0 | 139.2 | 69.9 | 33937.6 | 35 | 1400 | 1 |
| | .020 | 100.0 | 142.0 | 70.2 | 33357.5 | 46 | 1400 | 1 |
| | .020 | 200.0 | 141.3 | 70.8 | 33792.6 | 36 | 1400 | 1 |
| | .020 | 200.0 | 141.3 | 69.8 | 34227.7 | 39 | 1400 | 1 |
| | .020 | 502.0 | 139.8 | 70.3 | 35242.9 | 32 | 1400 | 1 |
| | .020 | 502.0 | 139.8 | 70.3 | 34082.7 | 32 | 1400 | 1 |
| | .020 | 1002.0 | 132.0 | 68.3 | 34372.7 | 17 | 1400 | 8 |
| | .020 | 1002.0 | 126.8 | 68.3 | 34952.9 | 16 | 1400 | 8 |
| | .020 | 2000.0 | 141.8 | 68.6 | 34372.7 | 21 | 1400 | 8 |
| | .020 | 2000.0 | 140.7 | 68.9 | 34662.8 | 21 | 1400 | 8 |
| | .020 | 5000.0 | 149.4 | 73.2 | 33937.6 | 16 | 1400 | 8 |
| | .020 | 5000.0 | 151.6 | 71.5 | 31762.1 | 17 | 1400 | 8 |
| | .020 | 25.0 | 137.2 | 61.8 | 33647.6 | 32 | 1800 | 1 |
| | .020 | 25.0 | 136.3 | 60.3 | 32487.3 | 32 | 1800 | 1 |
| | .020 | 50.0 | 137.2 | 61.3 | 33212.5 | 37 | 1800 | 1 |
| | .020 | 50.0 | 136.8 | 61.1 | 33937.6 | 38 | 1800 | 1 |
| | .020 | 100.0 | 133.7 | 58.3 | 33067.4 | 31 | 1800 | 1 |
| | .020 | 100.0 | 134.9 | 59.8 | 37418.4 | 32 | 1800 | 1 |
| | .020 | 200.0 | 126.3 | 62.5 | 35388.0 | 28 | 1800 | 1 |
| | .020 | 200.0 | 129.7 | 55.8 | 34082.7 | 28 | 1800 | 1 |
| | .020 | 50.0 | 130.7 | 64.2 | 34952.9 | 38 | 1800 | 8 |
| | .020 | 50.0 | 131.3 | 63.8 | 35242.9 | | 1800 | 8 |
| | .020 | 100.0 | 122.6 | 63.4 | 34952.9 | 23 | 1800 | 8 |
| | .020 | 200.0 | 119.2 | 61.8 | 33937.6 | 20 | 1800 | 8 |
| | .020 | 200.0 | 120.4 | 61.8 | 34082.7 | 20 | 1800 | 8 |
| | .020 | 500.0 | 115.9 | 60.2 | 34082.7 | 12 | 1800 | 8 |
| | .020 | 500.0 | 114.7 | 60.3 | 34227.7 | 16 | 1800 | 8 |
| | .020 | 1000.0 | 106.0 | 59.6 | 33212.5 | 16 | 1800 | 8 |
| | .020 | 1000.0 | 110.2 | 60.5 | 32777.4 | 15 | 1800 | 8 |
| | .020 | 2000.0 | 88.5 | 59.3 | 31327.0 | 10 | 1800 | 8 |
| | .020 | 2000.0 | 96.4 | 59.3 | 30746.9 | 14 | 1800 | 8 |
| | .020 | 3500.0 | 62.8 | 49.7 | 28716.5 | | 1800 | 8 |
| | .020 | 3500.0 | 70.6 | 54.2 | 31327.0 | | 1800 | 8 |
| | .020 | 5000.0 | 49.6 | 55.7 | 25380.7 | 2 | 1800 | 8 |
| | .020 | 5000.0 | 53.2 | 42.3 | | 3 | 1800 | 8 |

TABLE VIII.- RESIDUAL MATERIAL PROPERTIES AFTER ELEVATED-TEMPERATURE EXPOSURE WITHOUT STRESS – Concluded

(b) U.S. Customary Units – Concluded

| Sheet thickness, in. | Exposure, hr | Tensile strength, ksi | Yield strength, ksi | Modulus of elasticity, ksi | Elongation in 1 in., percent | Temperature, °F | Pressure, torr |
|---|---|---|---|---|---|---|---|
| TD NiCr | | | | | | | |
| .020 | 50.0 | 137.5 | 92.8 | 23930.4 | 20 | 1400 | 1 |
| .020 | 50.0 | 136.3 | 93.8 | 25235.7 | 17 | 1400 | 1 |
| .020 | 100.0 | 140.8 | 95.4 | 25815.8 | 18 | 1400 | 1 |
| .020 | 100.0 | 133.4 | 89.8 | 23495.3 | 14 | 1400 | 1 |
| .020 | 200.0 | 139.2 | 94.1 | 24655.5 | 18 | 1400 | 1 |
| .020 | 200.0 | 135.2 | 91.5 | 24800.6 | 19 | 1400 | 1 |
| .020 | 502.0 | 136.2 | 89.9 | 24365.5 | 18 | 1400 | 1 |
| .020 | 502.0 | 135.6 | 89.9 | 24365.5 | 21 | 1400 | 1 |
| .020 | 1002.0 | 128.2 | 90.9 | 24800.6 | 12 | 1400 | 8 |
| .020 | 1002.0 | 136.0 | 90.1 | 24800.6 | 18 | 1400 | 8 |
| .020 | 2000.0 | 137.5 | 92.0 | 24365.5 | 18 | 1400 | 8 |
| .020 | 2000.0 | 139.2 | 93.1 | 24945.6 | 19 | 1400 | 8 |
| .020 | 5000.0 | 135.2 | 87.7 | 24075.4 | 18 | 1400 | 8 |
| .020 | 5000.0 | 135.8 | 86.1 | 24220.4 | 15 | 1400 | 8 |
| .020 | 50.0 | 128.6 | 89.1 | 23495.3 | 13 | 1800 | 1 |
| .020 | 100.0 | 137.9 | 92.2 | 23495.3 | 18 | 1800 | 1 |
| .020 | 200.0 | 138.4 | 91.7 | 23640.3 | 19 | 1800 | 1 |
| .020 | 1000.0 | 136.5 | 89.8 | 22480.1 | 19 | 1800 | 8 |
| .020 | 2000.0 | 144.3 | 93.1 | 23495.3 | 17 | 1800 | 8 |
| .020 | 5000.0 | 121.2 | | 24800.6 | 10 | 1800 | 8 |

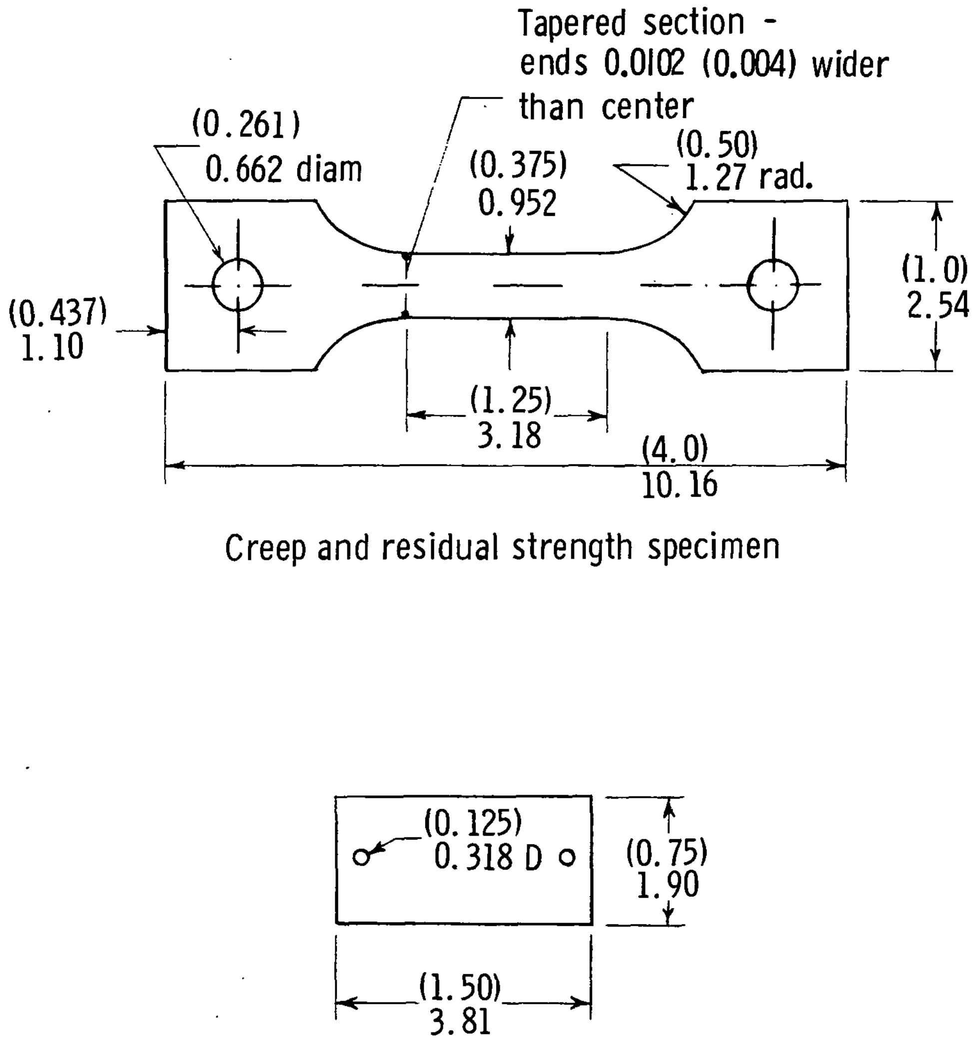
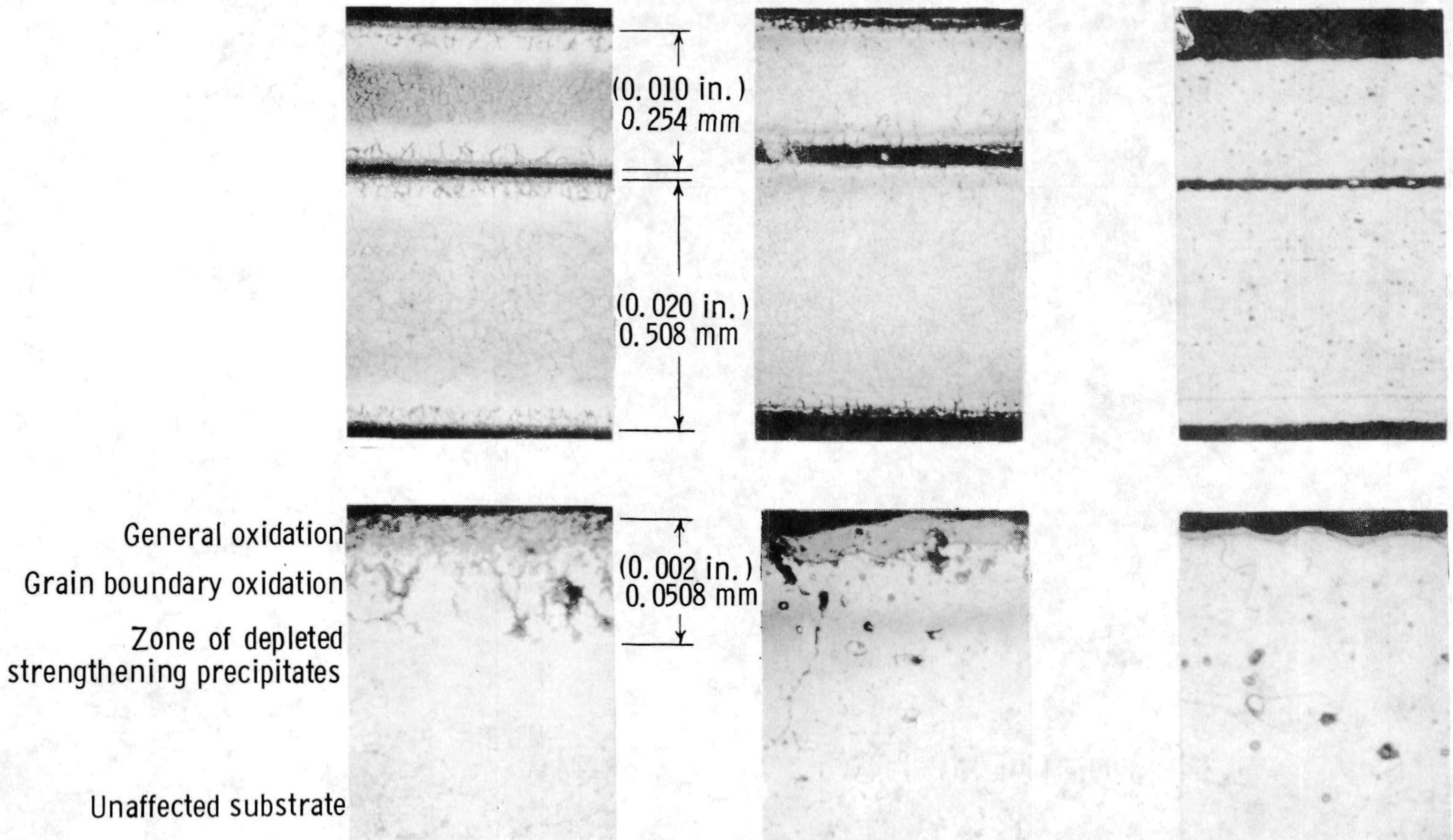



Figure 1.- Test-specimen configurations. All measurements in centimeters (in.).




René 41 after 100 hours, 1256 K (1800°F), 1.0664 kN/m$^2$ (8 torr)

Haynes 188 after 1000 hours, 1256 K (1800°F), 1.0664 kN/m$^2$ (8 torr)

TD NiCr after 200 hours, 1478 K (2200°F), 101.3 kN/m$^2$ (760 torr)

Figure 2.- Microstructure of oxidation specimens after exposure.

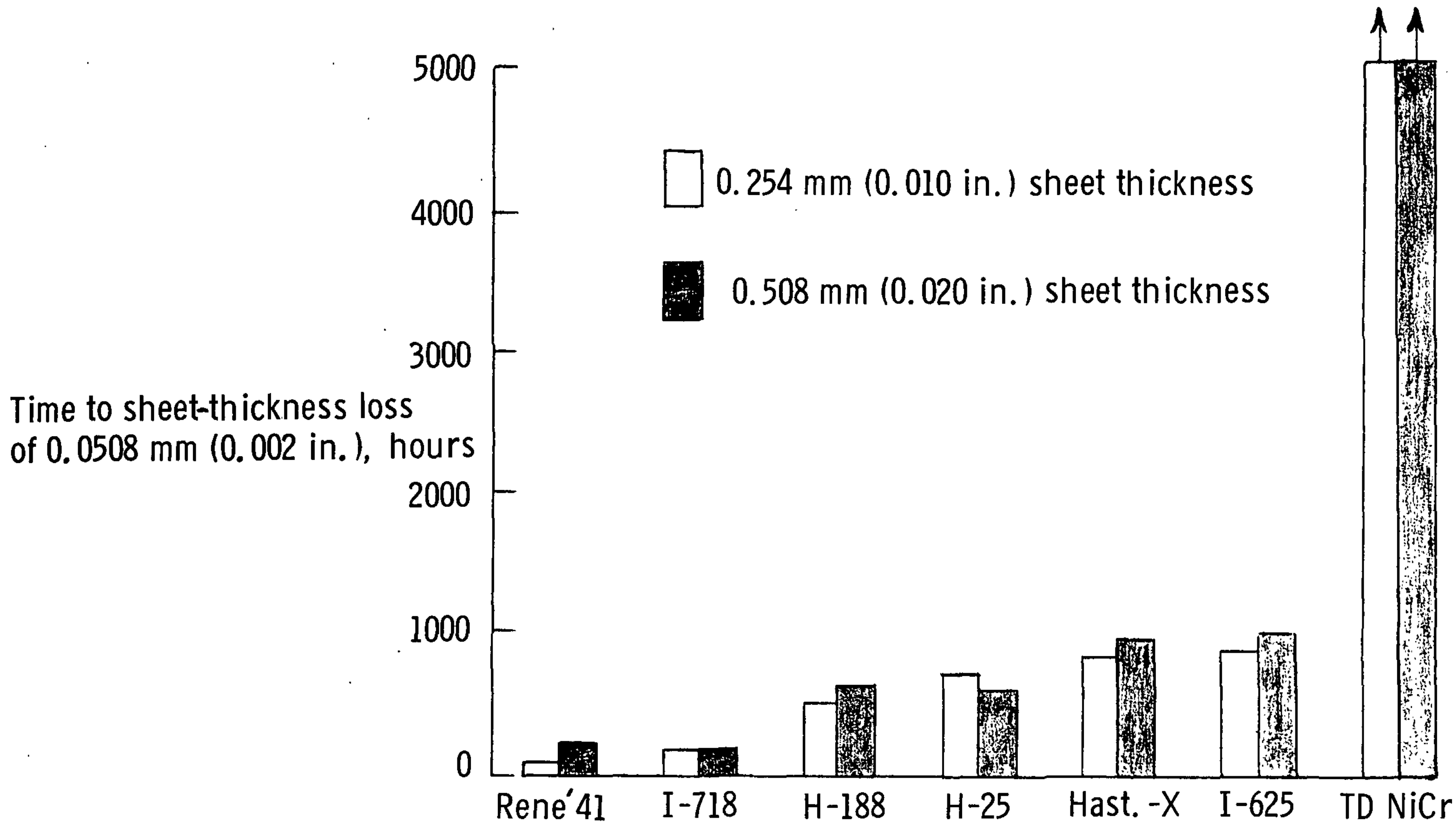



Figure 3.- Continuous oxidation tests at 1256 K (1800$^{\circ}$ F) and 1.0664 kN/m$^2$ (8 torr).

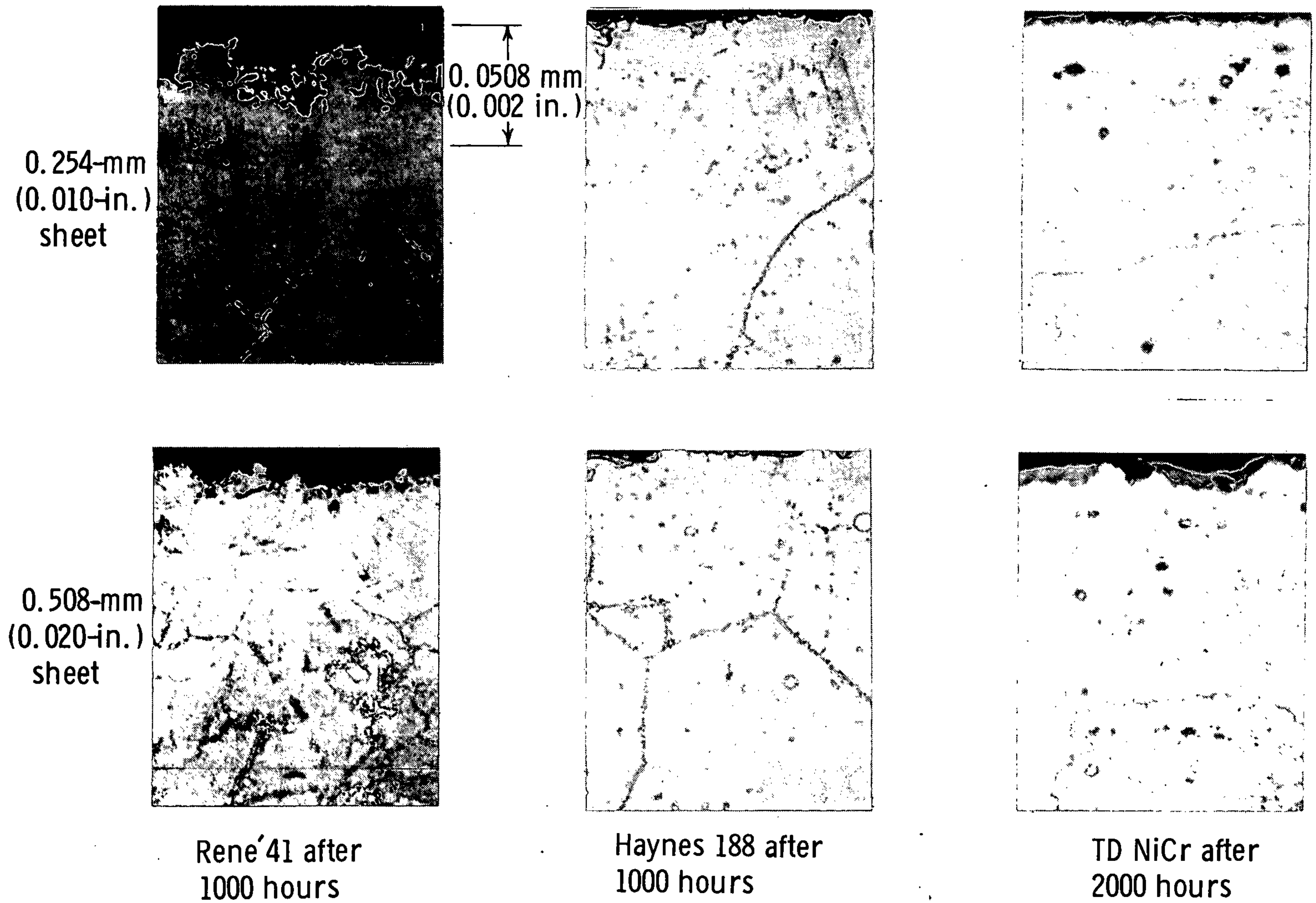



Figure 4.- Microstructure of oxidation specimens after exposure at 1033 K (1400° F), 1.0664 kN/m$^2$ (8 torr).

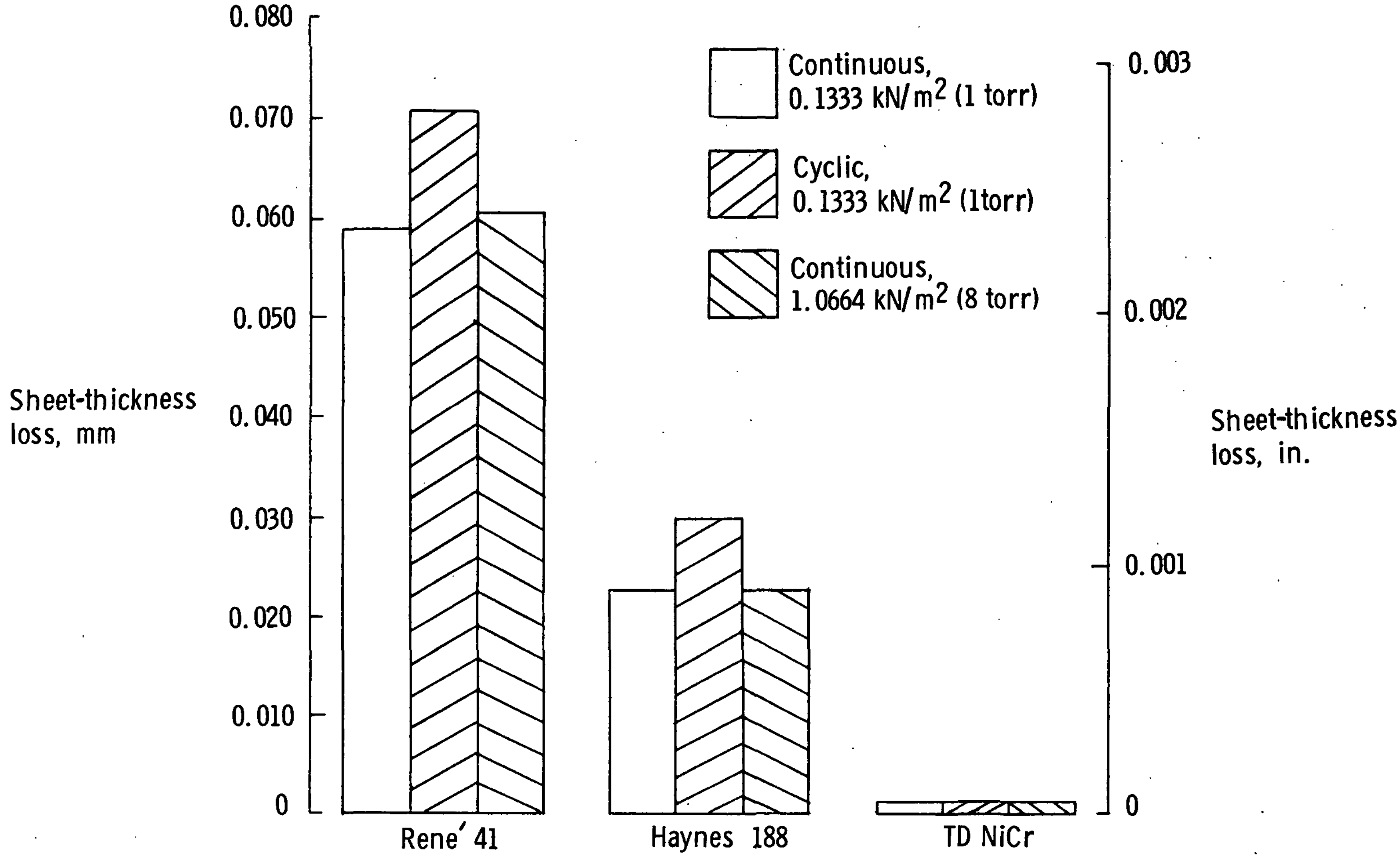
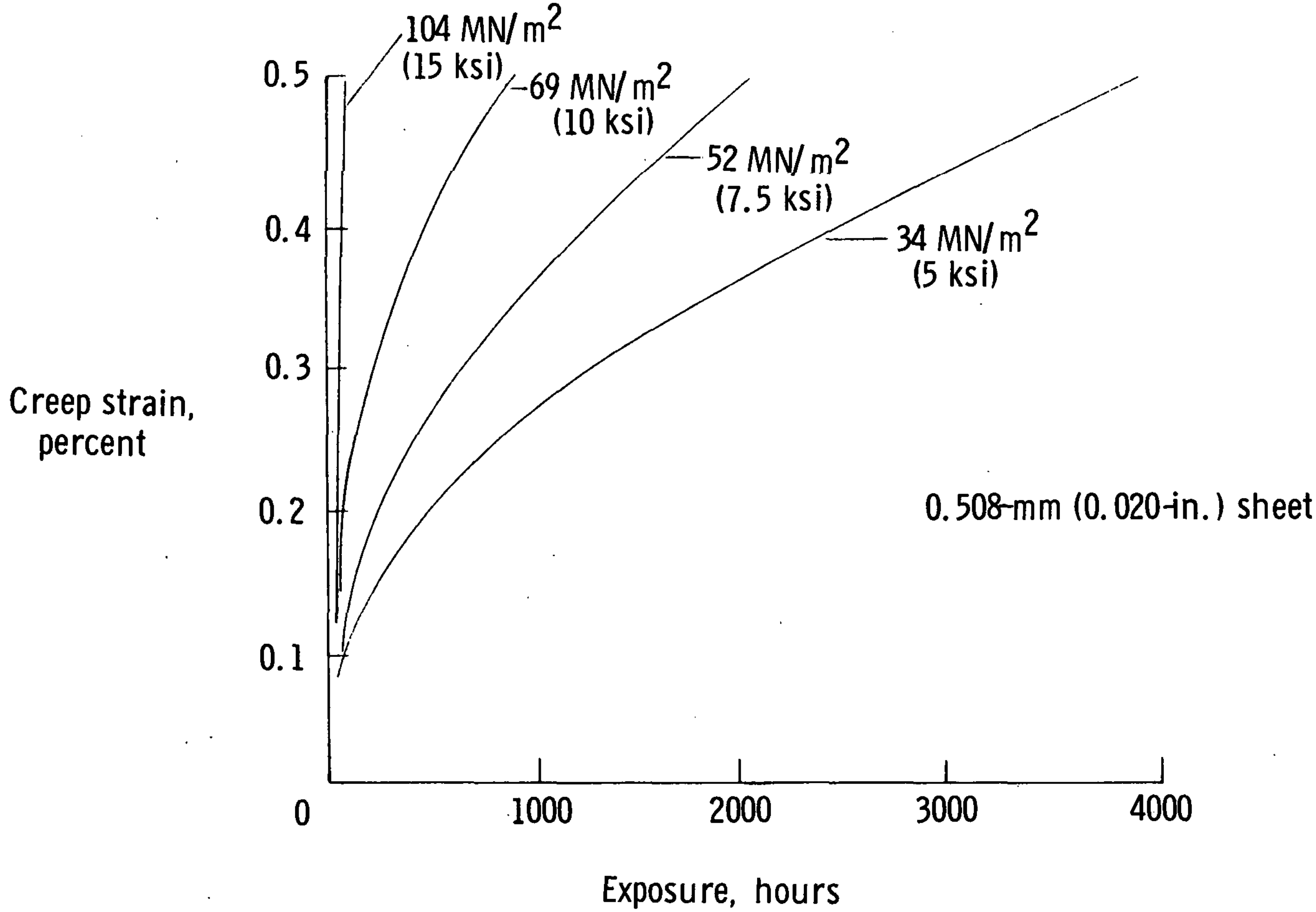
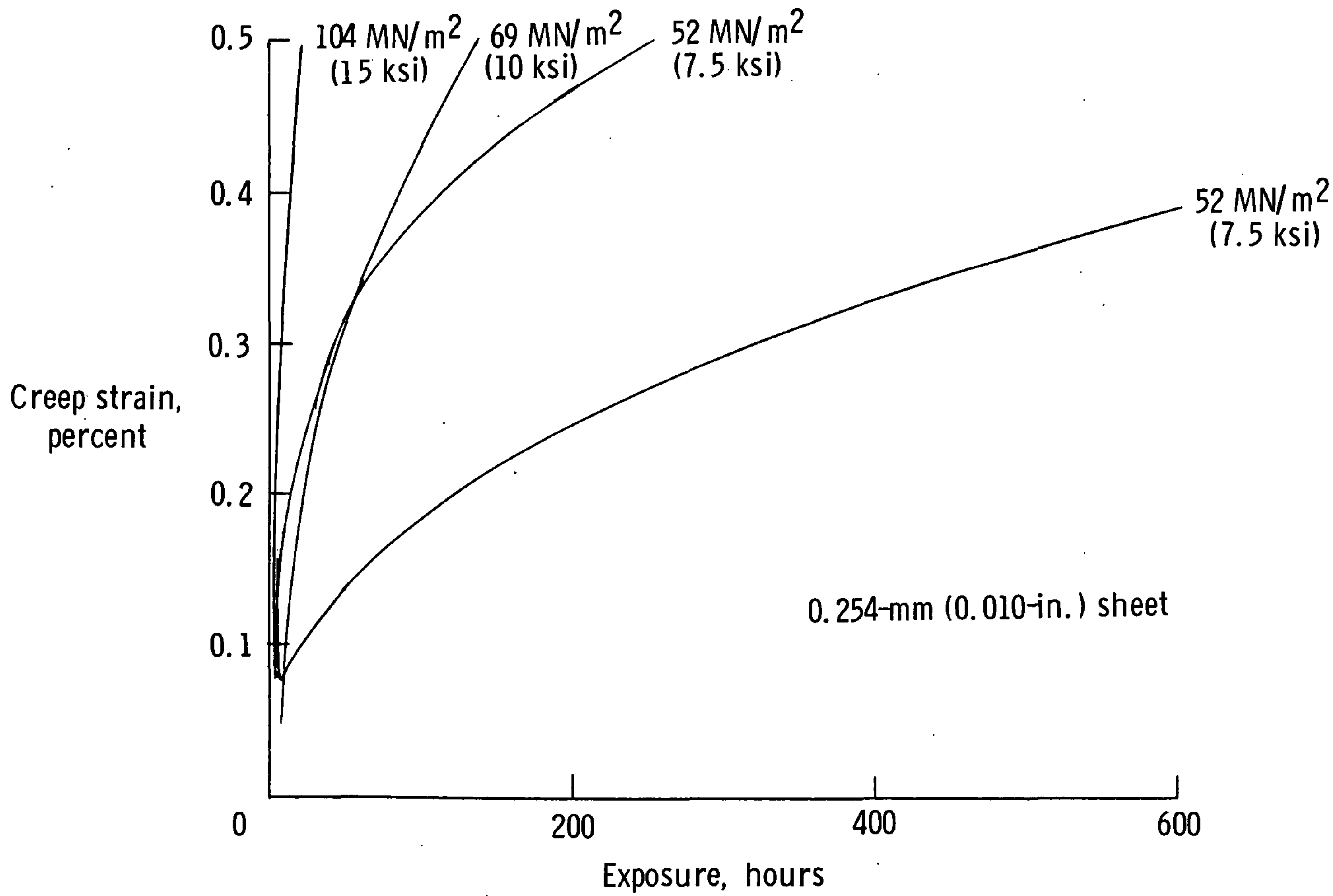



Figure 5.- Results of 100-hour cumulative exposure at 1256 K (1800° F) on 0.508-mm (0.020-in.) thick oxidation specimens subjected to continuous and half-hour cyclic exposures.



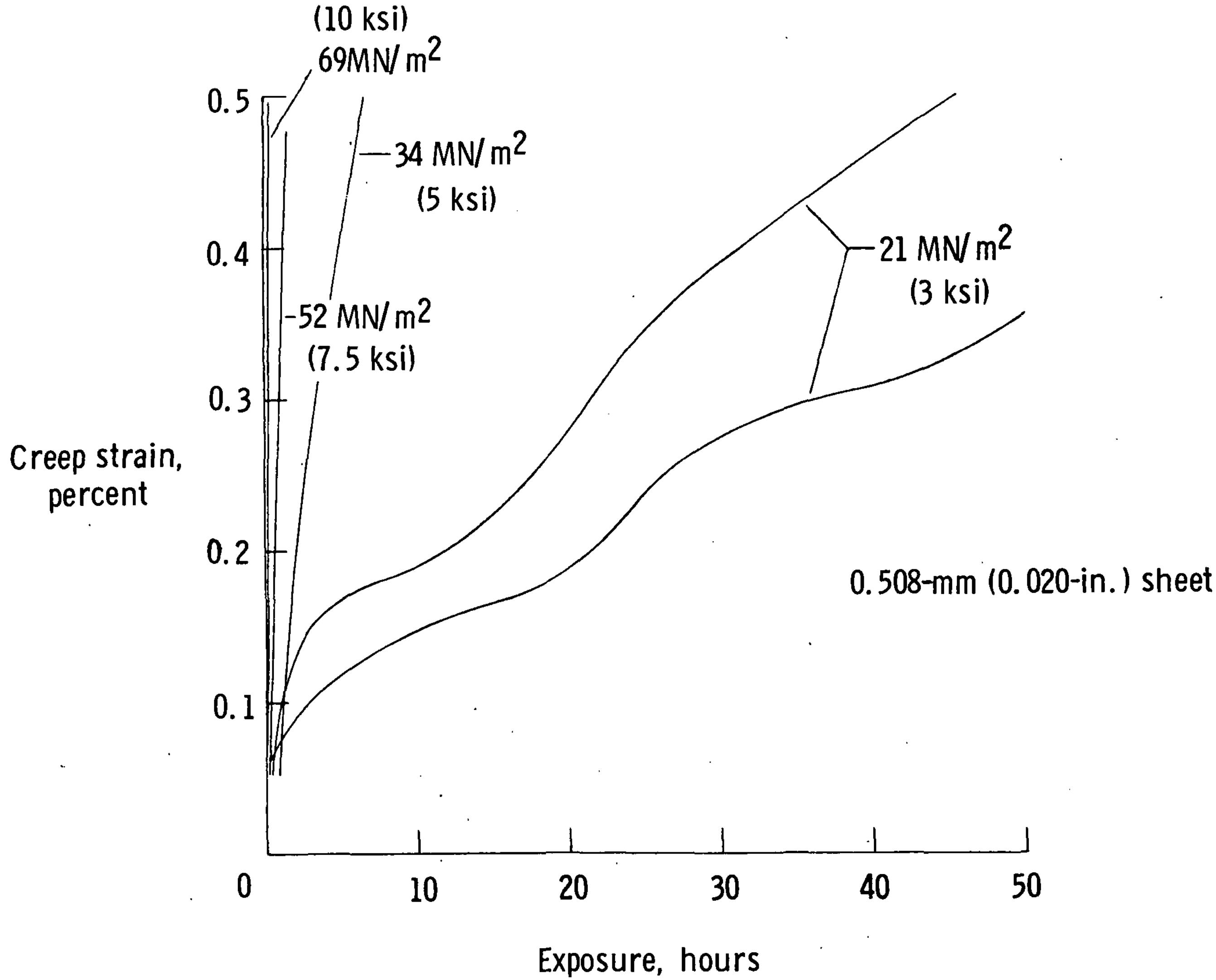

(a) 1033 K (1400° F) at 1.0664 kN/m$^2$ (8 torr).

Figure 6.- Creep curves for Haynes 188.



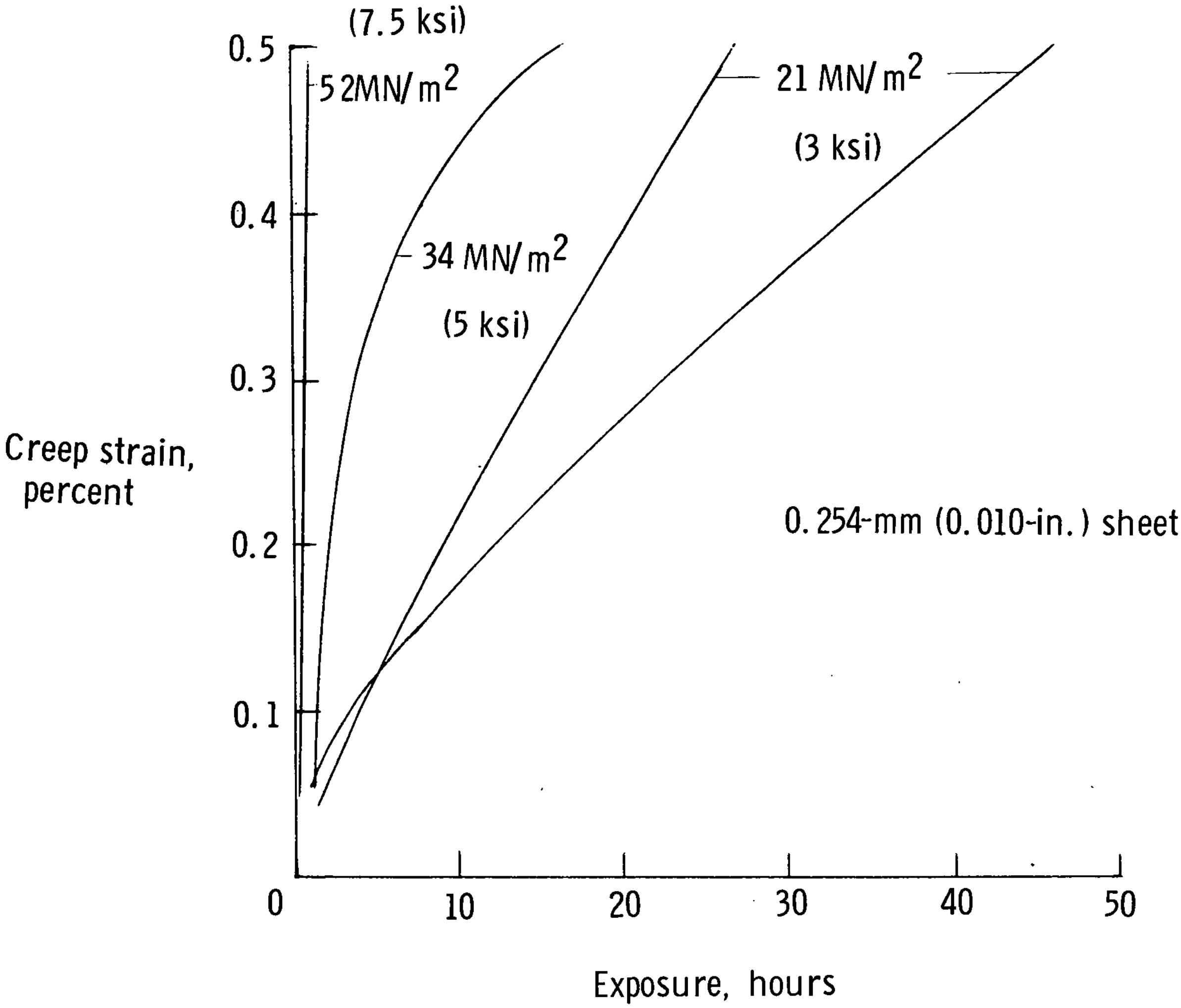

(a) Concluded.

Figure 6.- Continued.



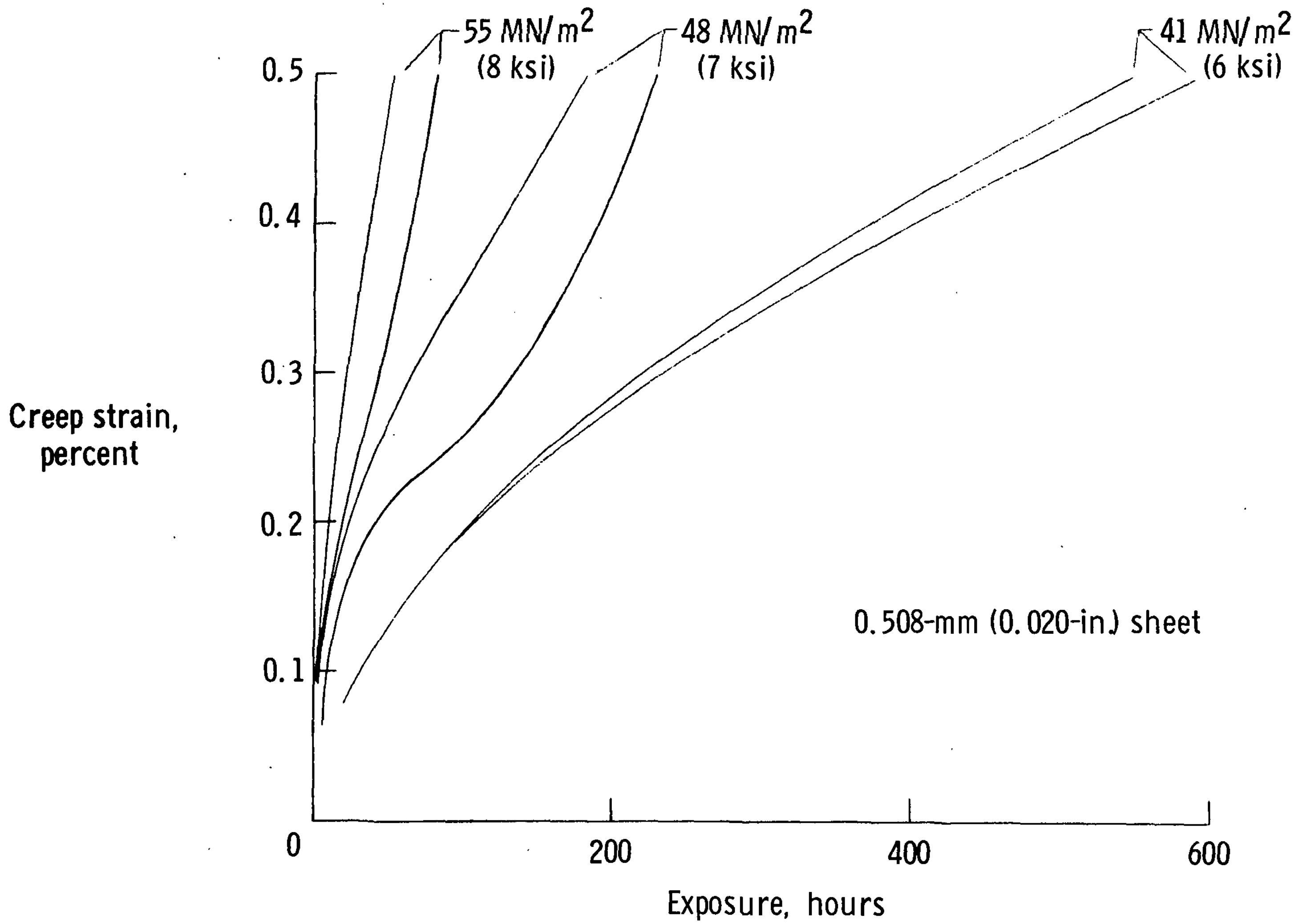

(b) 1256 K (1800$^{\circ}$ F) at 1.0664 kN/m$^2$ (8 torr).

Figure 6.- Continued.



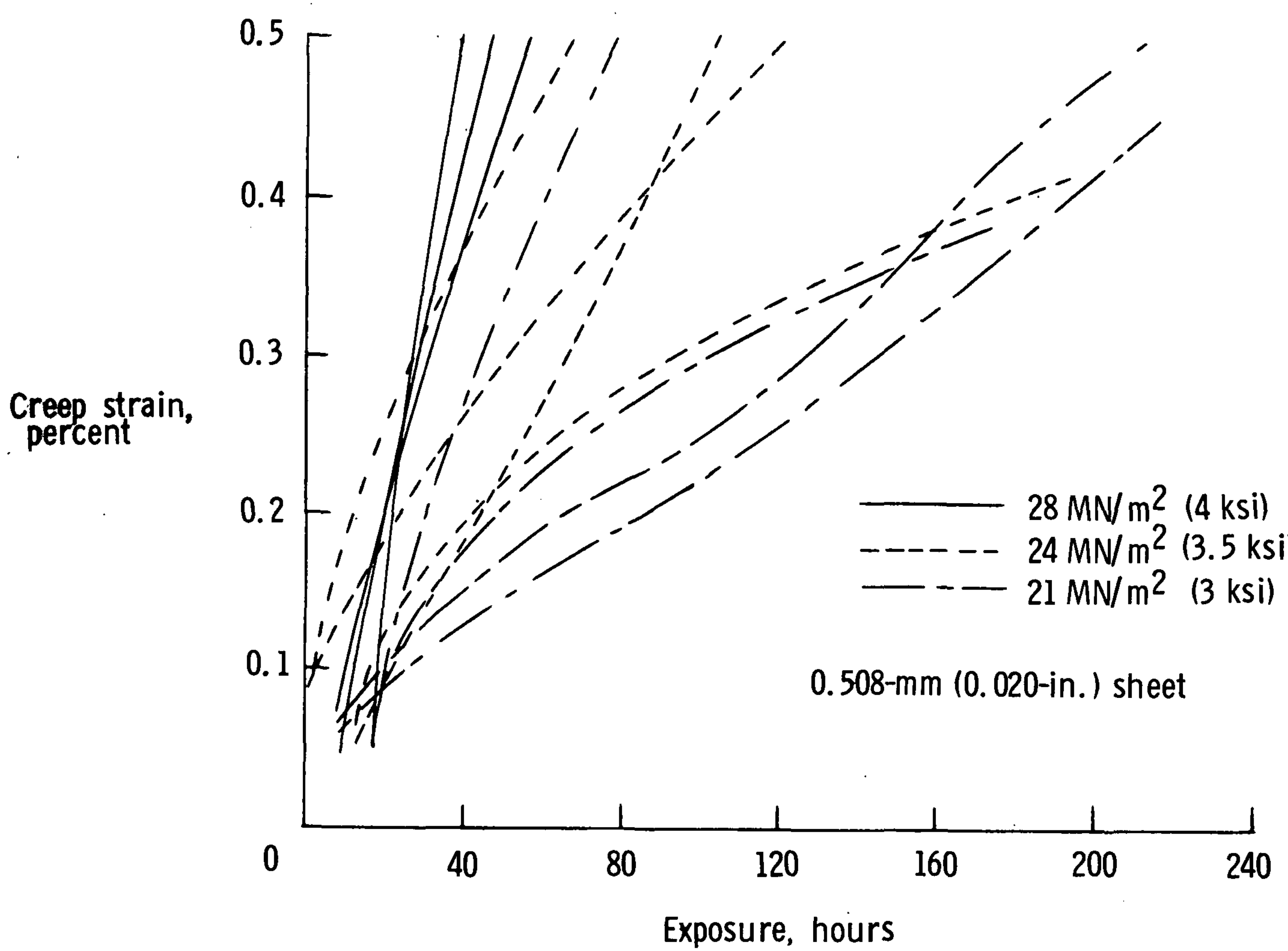

(b) Concluded.

Figure 6.- Continued.



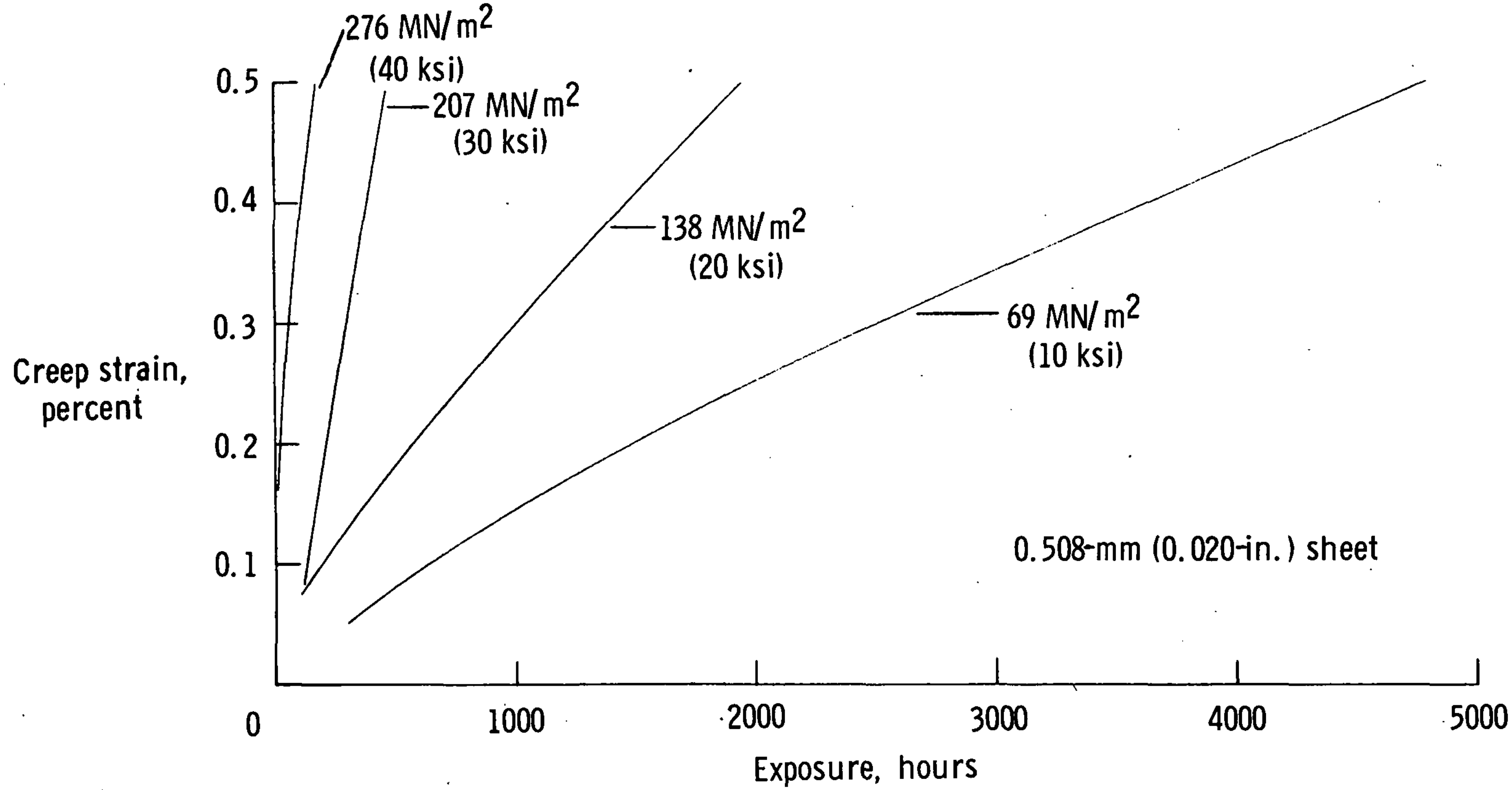

(c) 1145 K (1600° F) at 0.1333 $kN/m^2$ (1 torr).

Figure 6.- Continued.



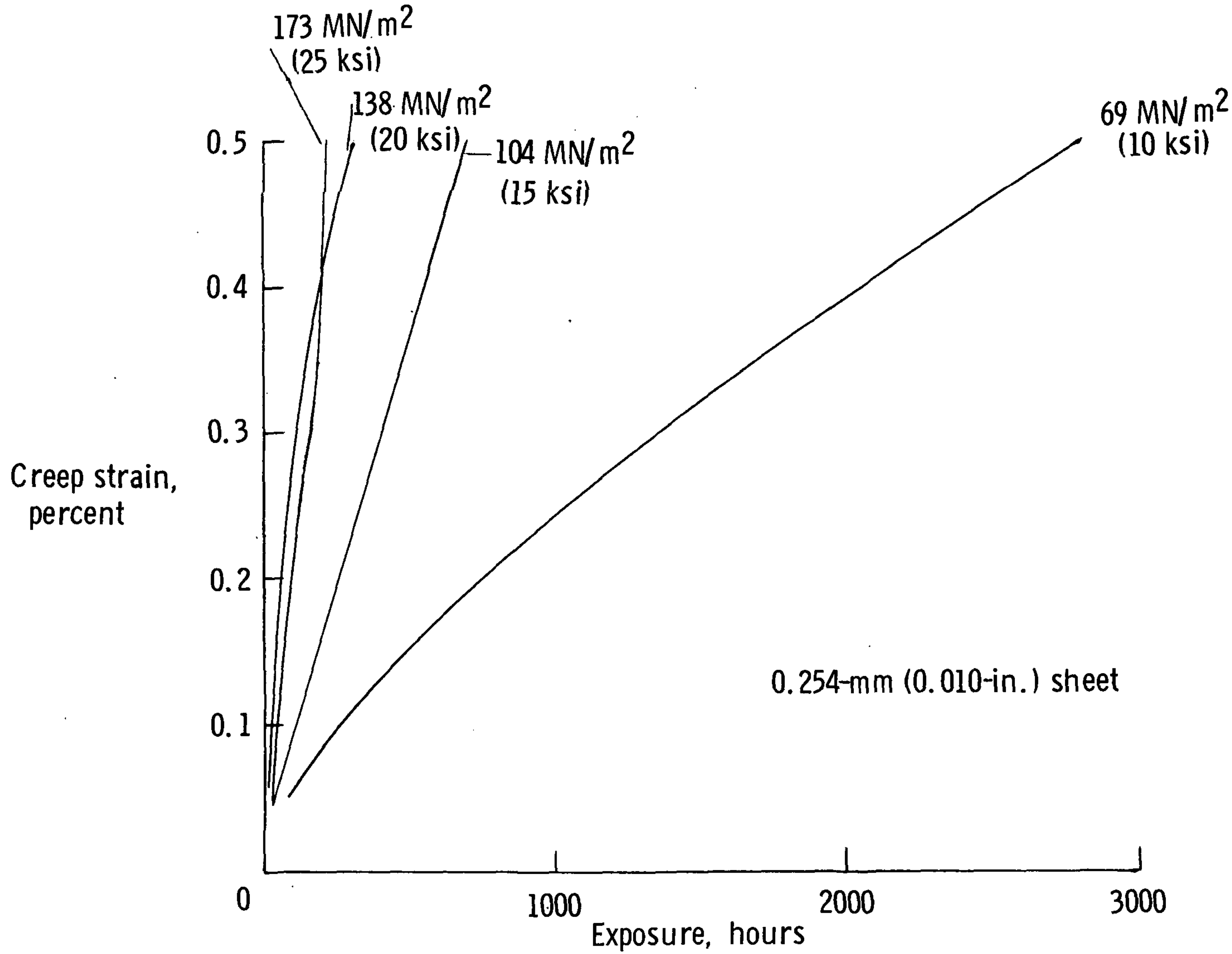

(d) 1256 K (1800° F) at 0.1333 $kN/m^2$ (1 torr).

Figure 6.- Concluded.



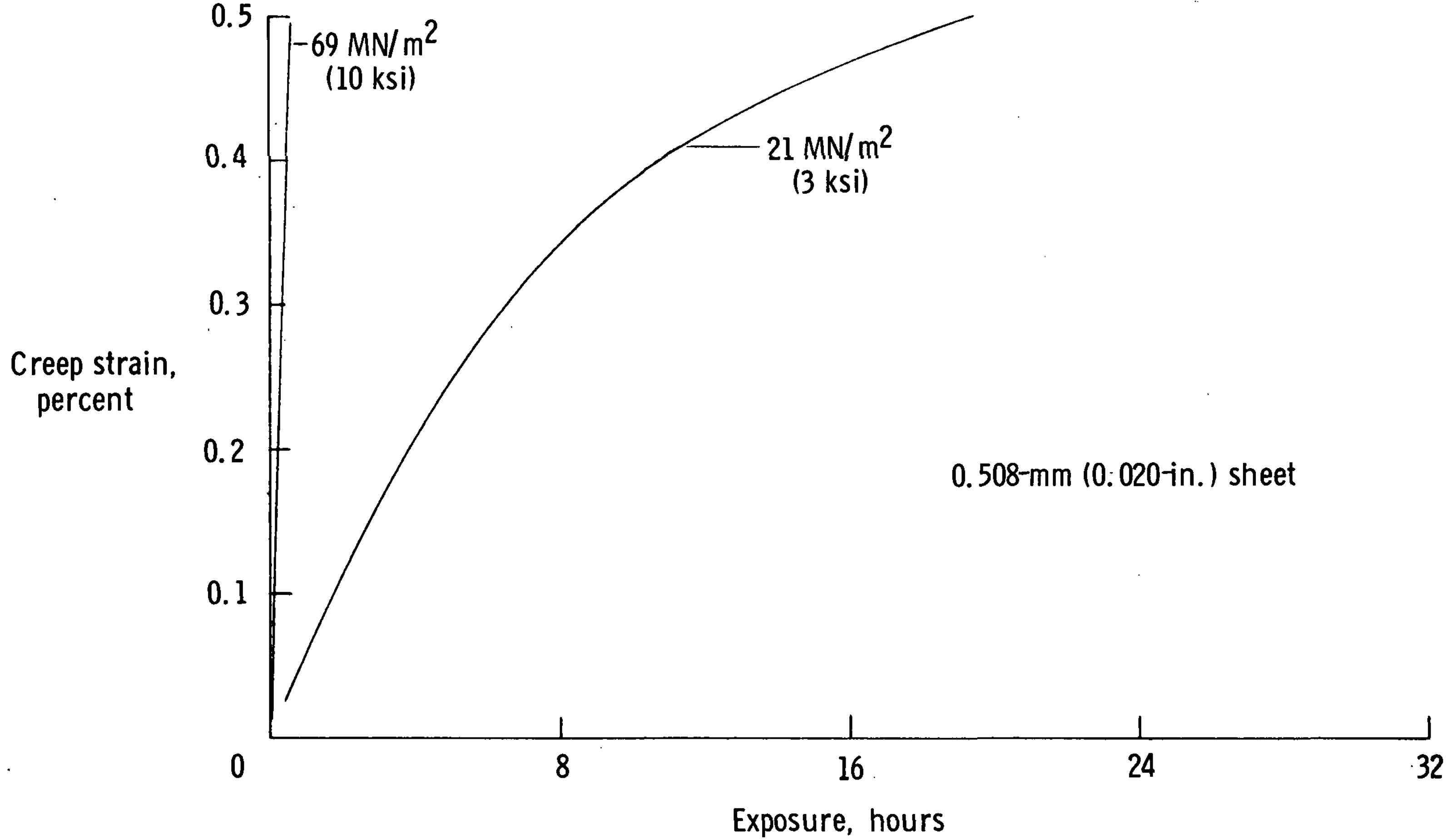

(a) 1033 K (1400° F) at 1.0664 kN/m$^2$ (8 torr).

Figure 7.- Creep curves for René 41.



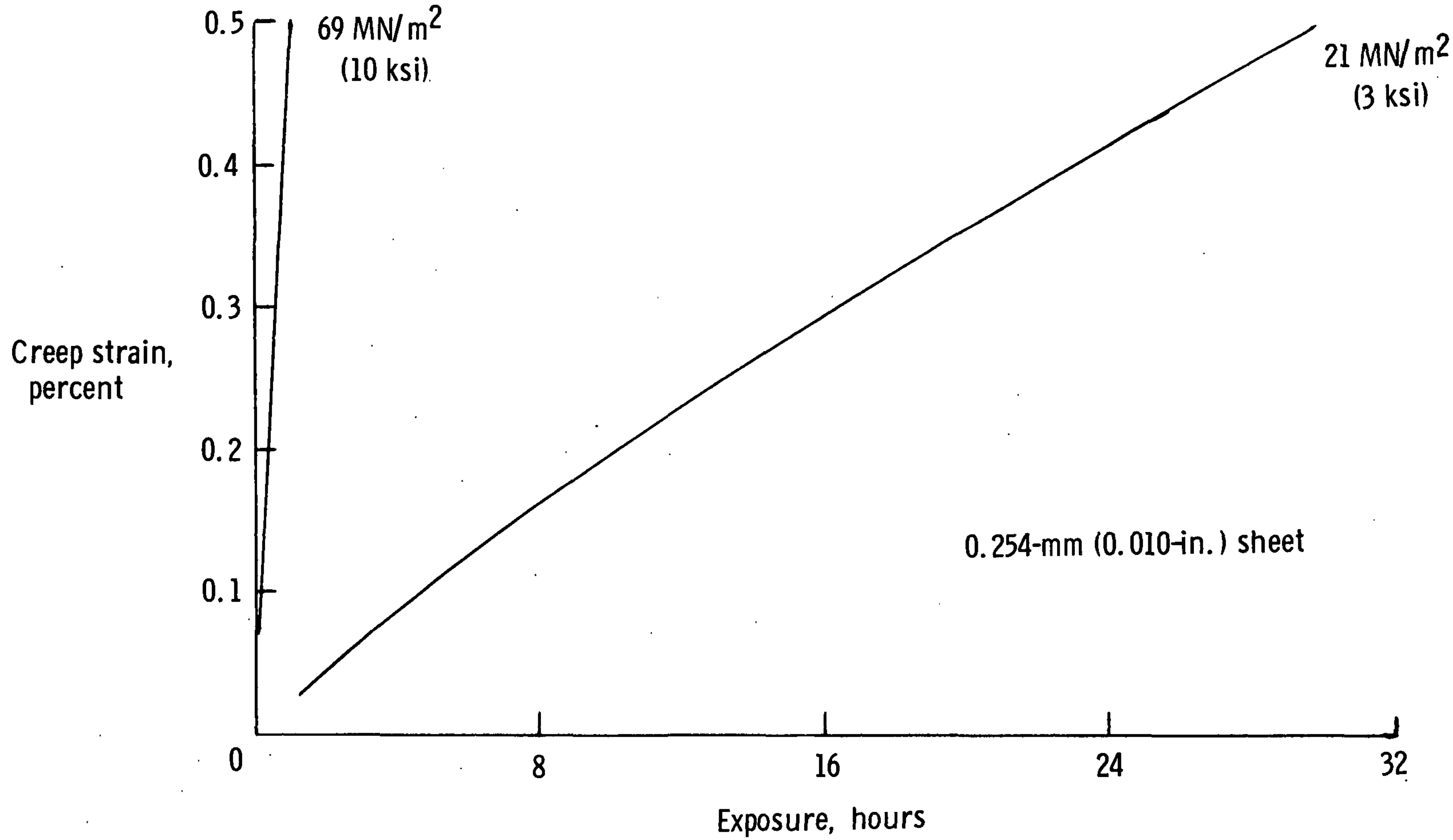

(a) Concluded.

Figure 7.- Continued.



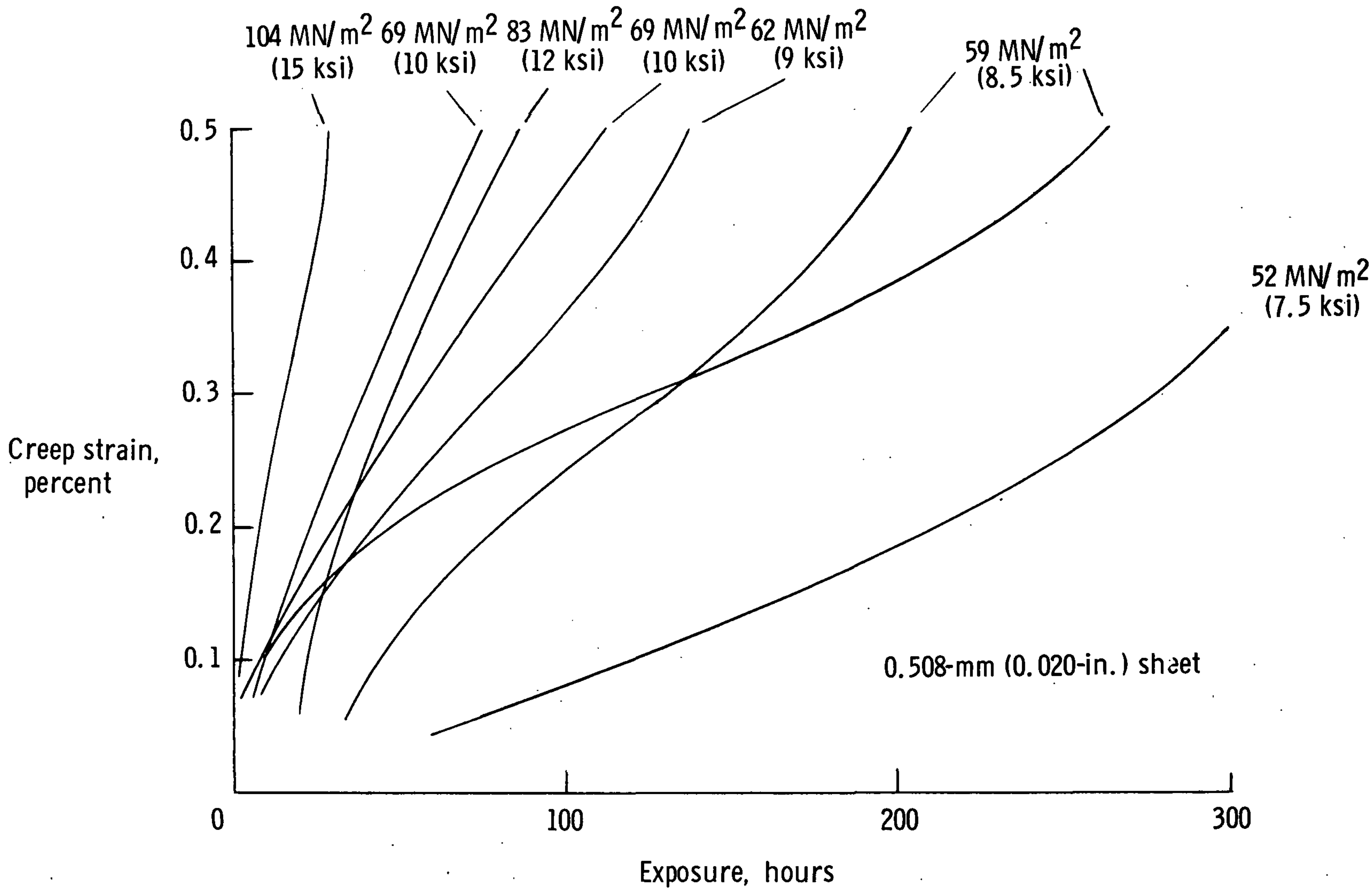

(b) 1256 K (1800° F) 1.0664 kN/m$^2$ (8 torr).

Figure 7.- Continued.



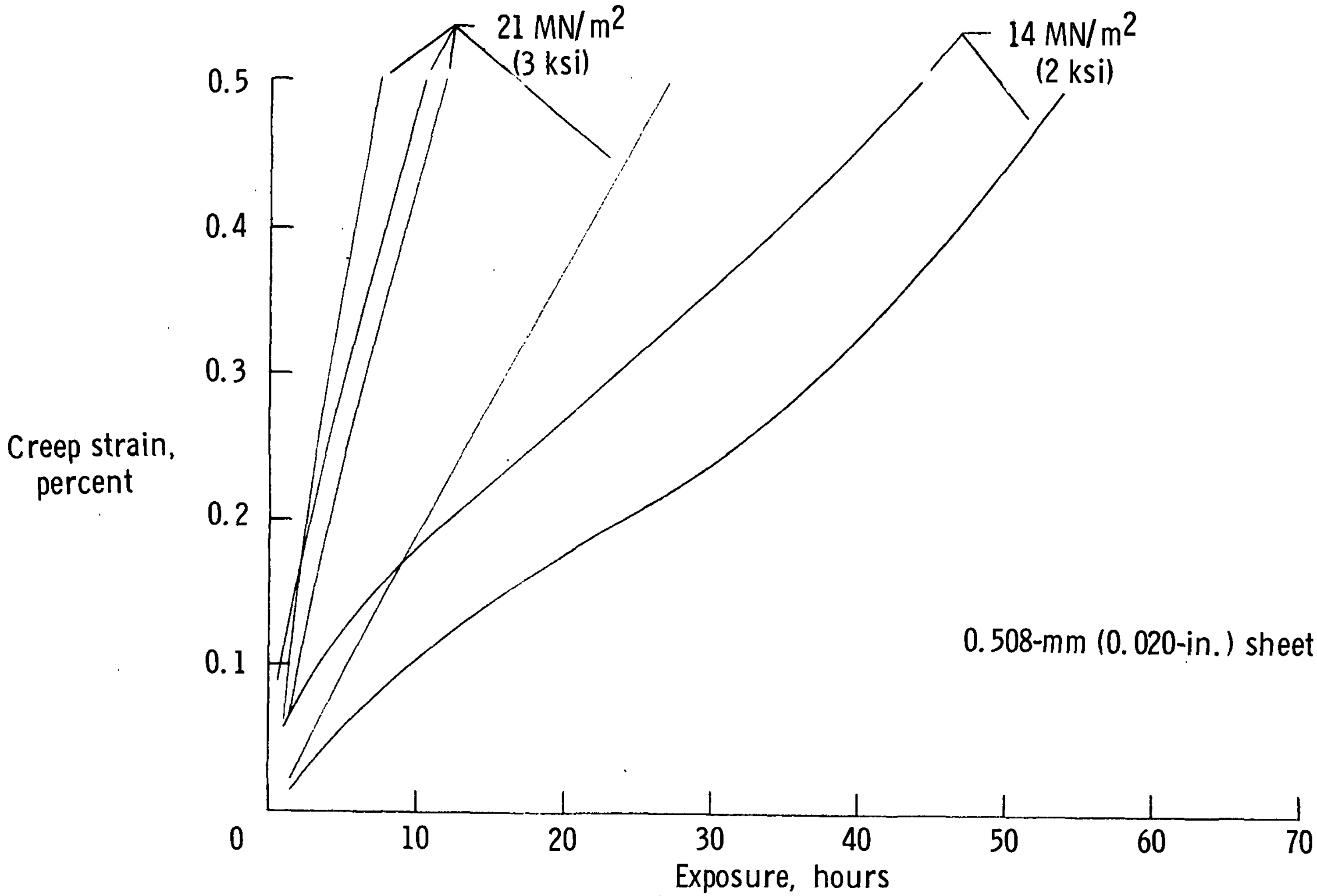

(b) Concluded.

Figure 7.- Continued.




(c) 1145 K (1600° F) at 0.1333 kN/$m^2$ (1 torr).

Figure 7.- Continued.




(d) 1256 K (1800° F) at 0.1333 $kN/m^2$ (1 torr).

Figure 7.- Concluded.

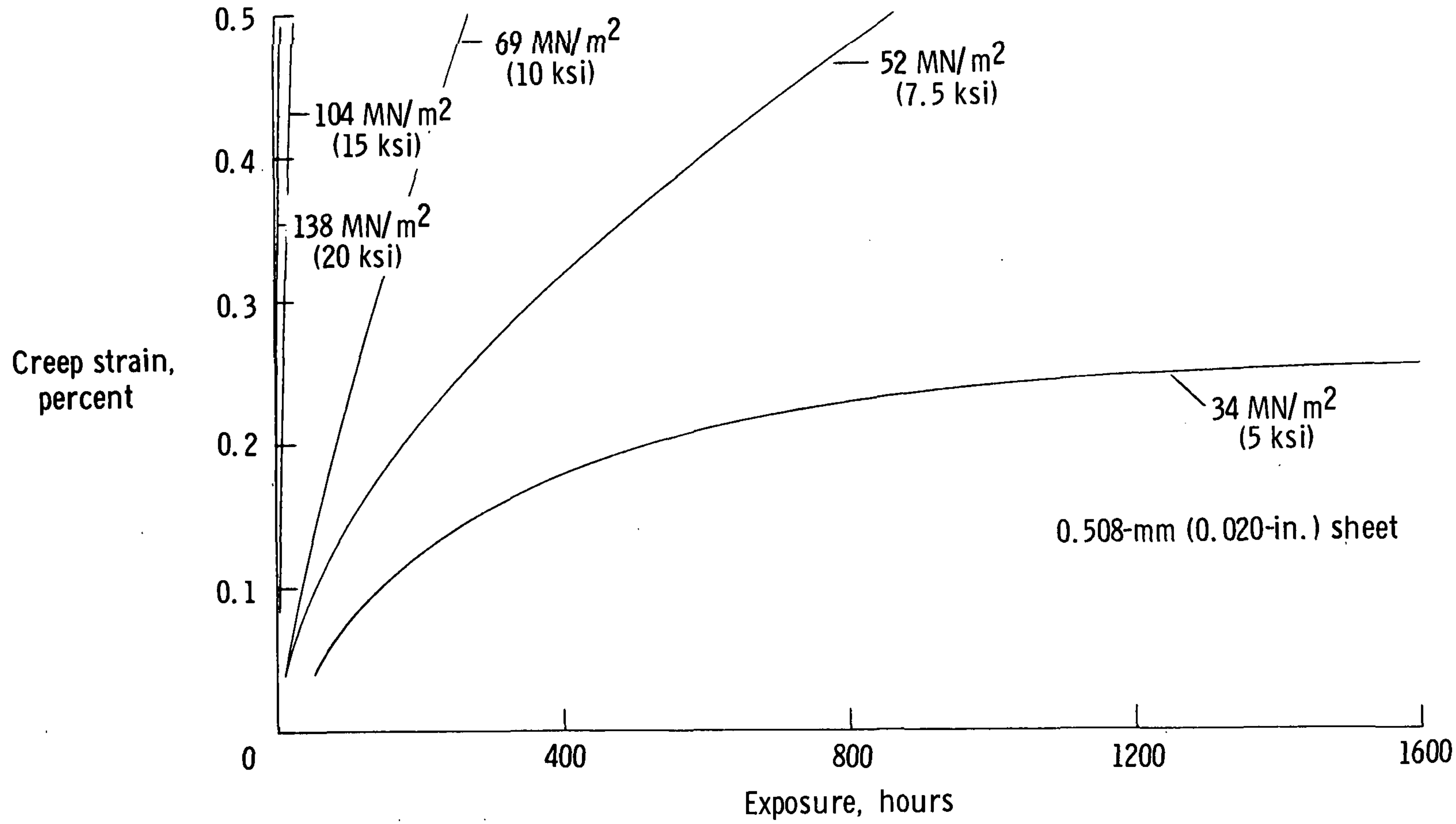



Figure 8.- Creep curves for Hastelloy X. 1033 K (1400° F) at 1.0664 $kN/m^2$ (8 torr).

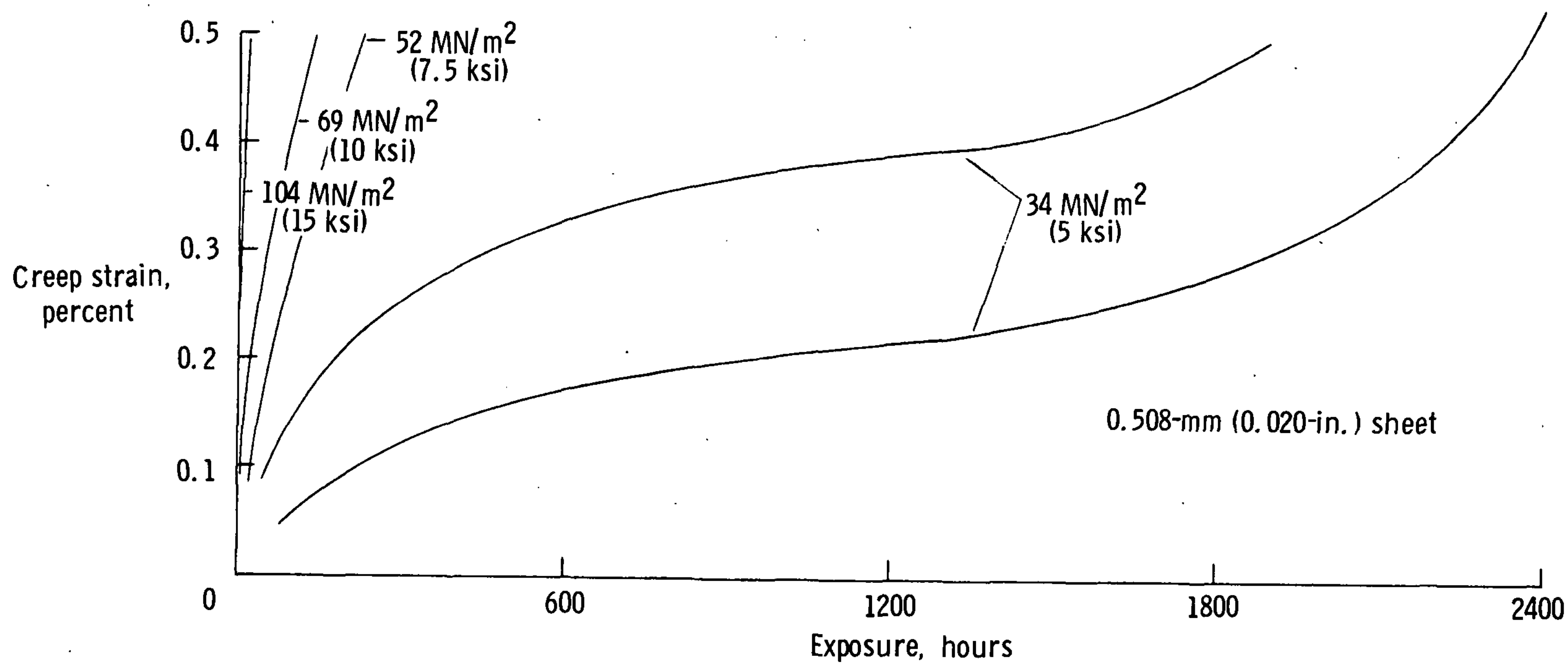



Figure 9.- Creep curves for Inconel 625. 1033 K (1400° F) at 1.0664 kN/m$^2$ (8 torr).

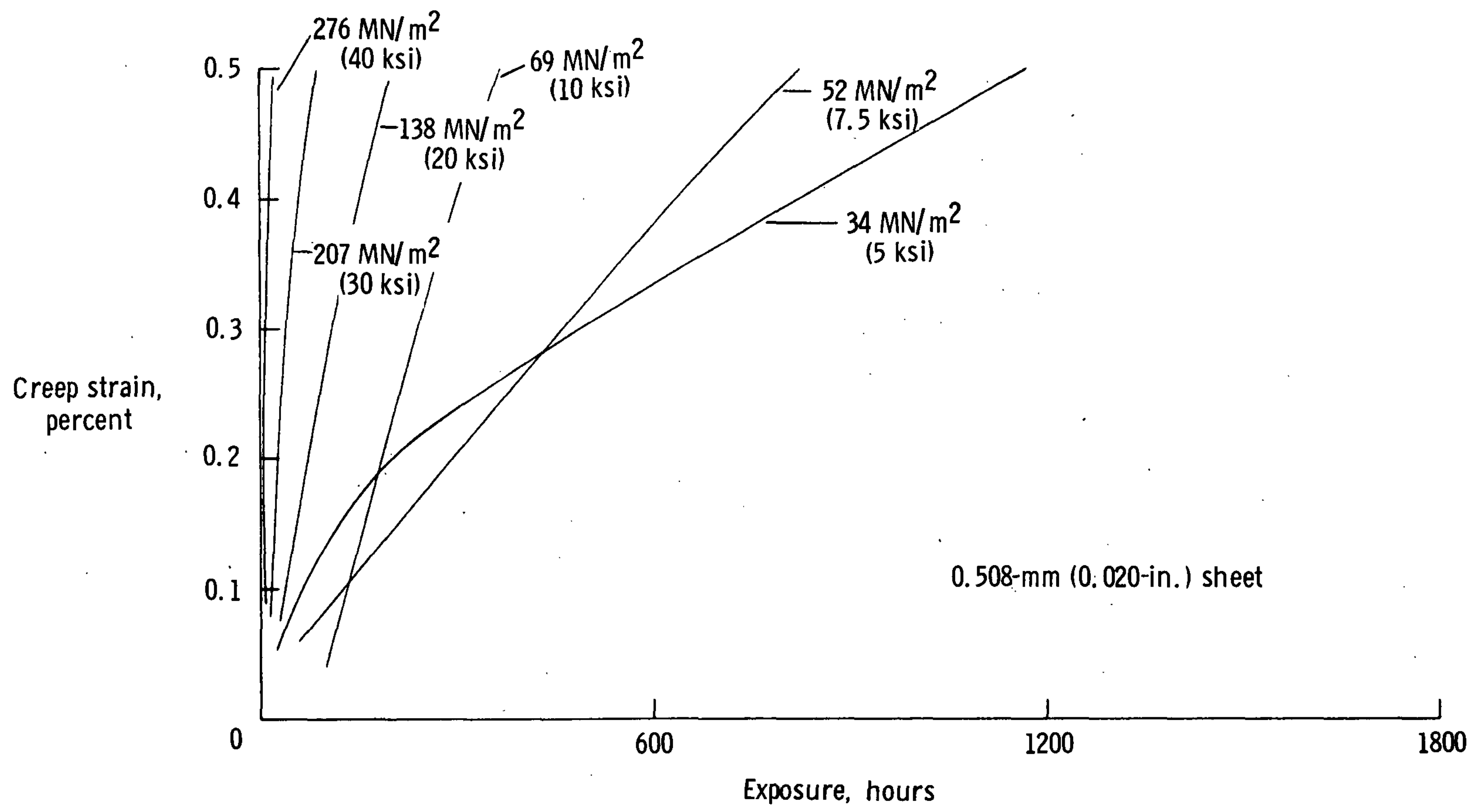



Figure 10.- Creep curves for Inconel 718. 1033 K (1400° F) at 1.0664 kN/$m^2$ (8 torr).

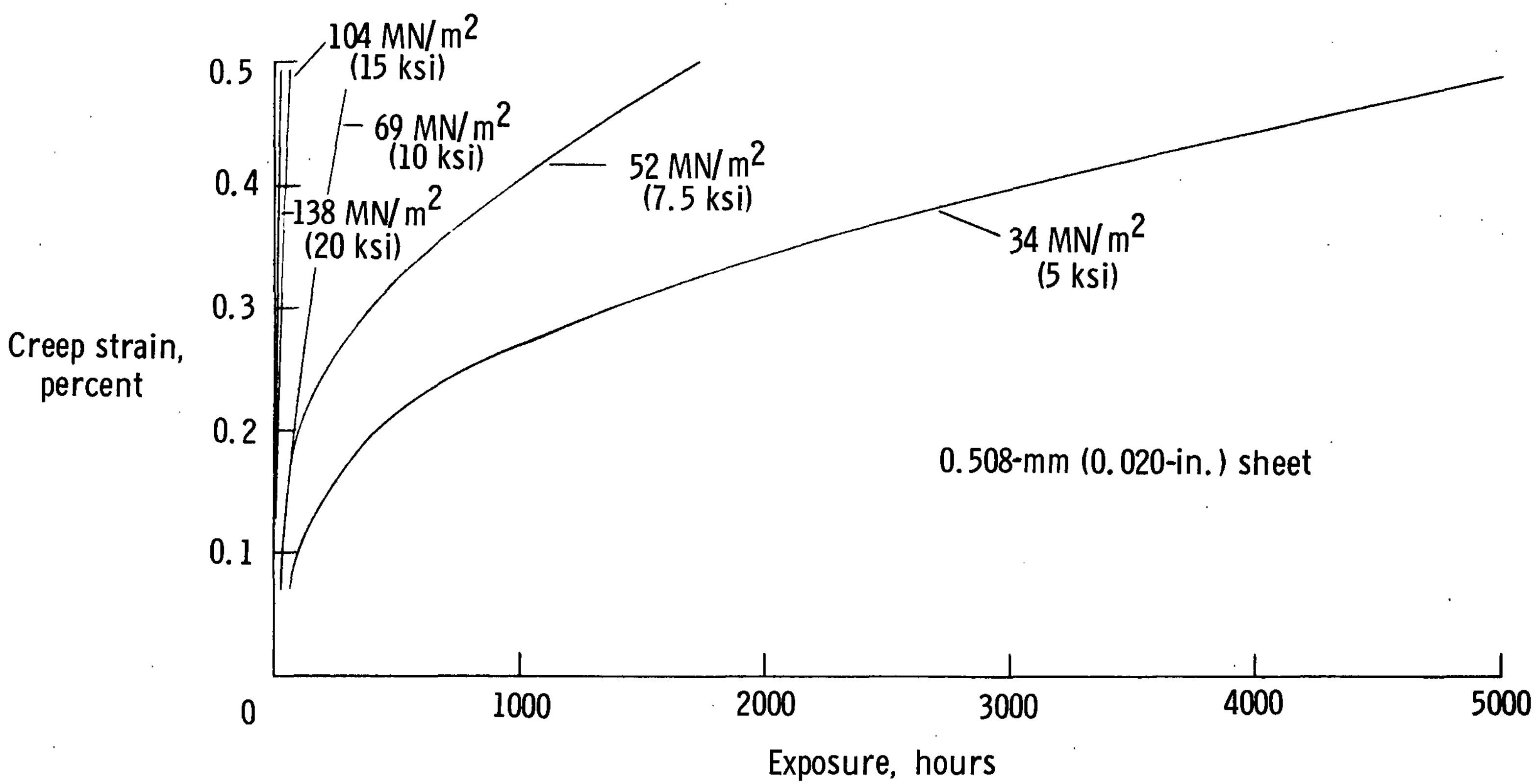
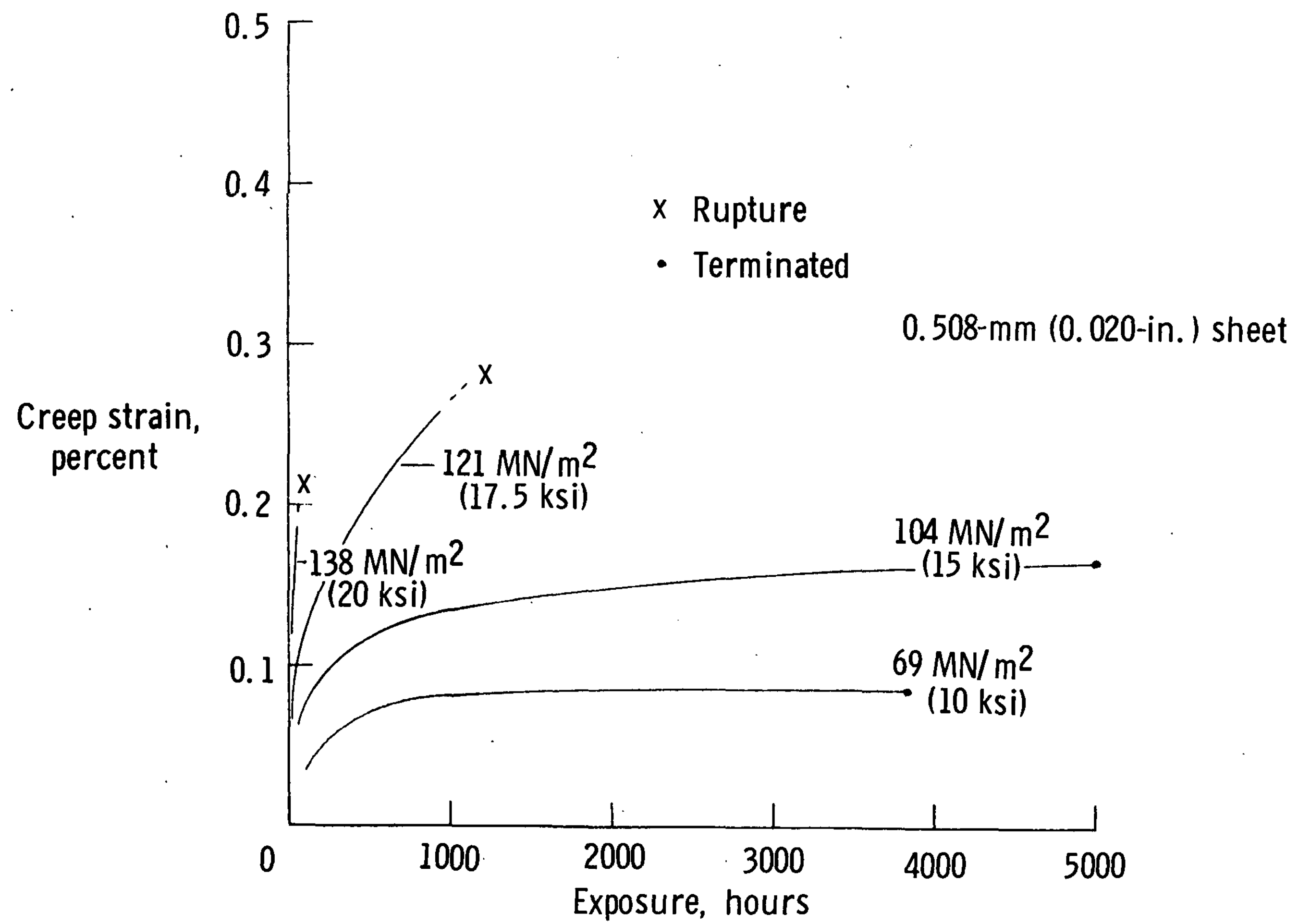
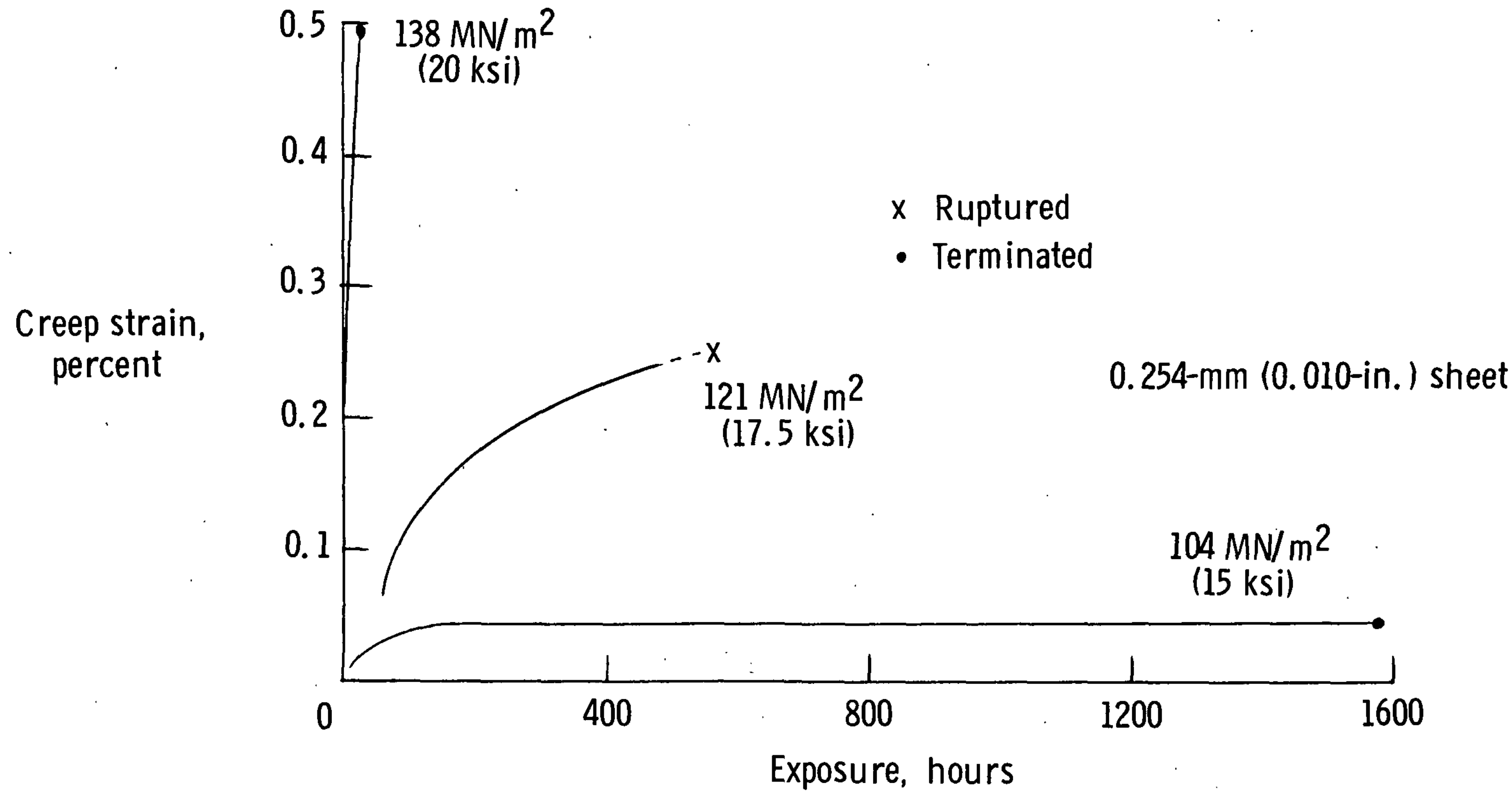



Figure 11.- Creep curves for Haynes 25. 1033 K (1400° F) at 1.0664 kN/m$^2$ (8 torr).



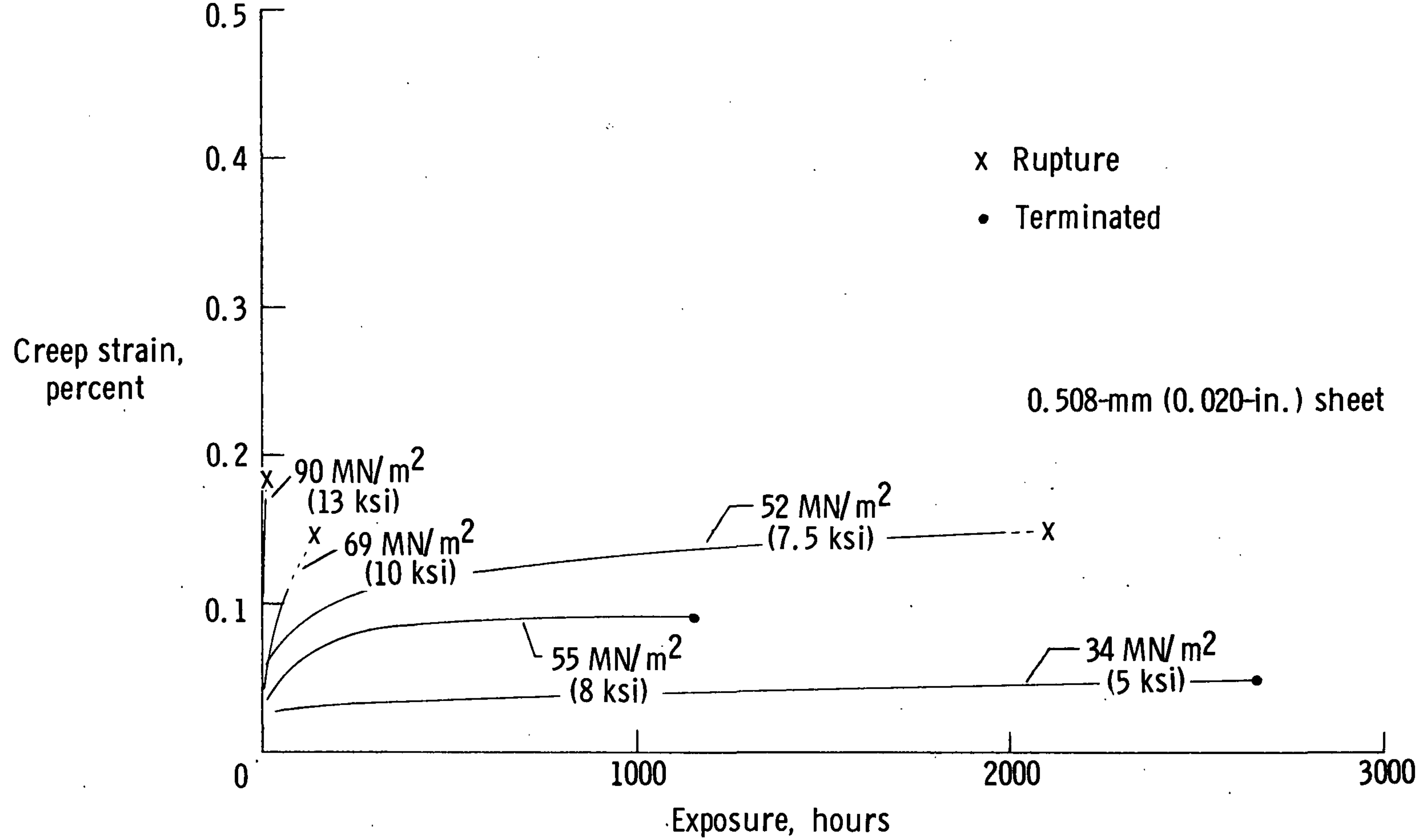

(a) 1033 K (1400° F) at 1.0664 kN/m$^2$ (8 torr).

Figure 12.- Creep curves for TD NiCr.



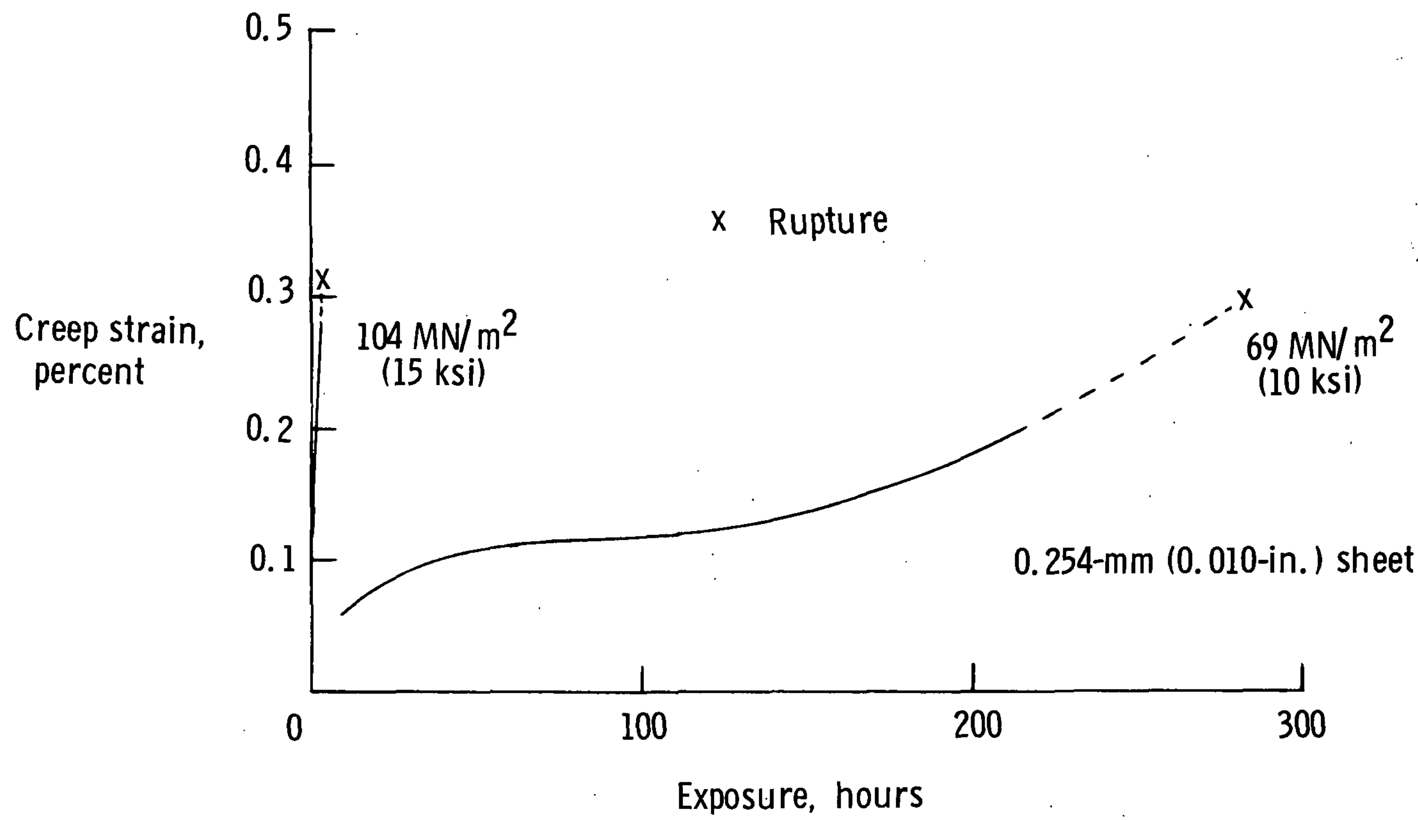

(a) Concluded.

Figure 12.- Continued.



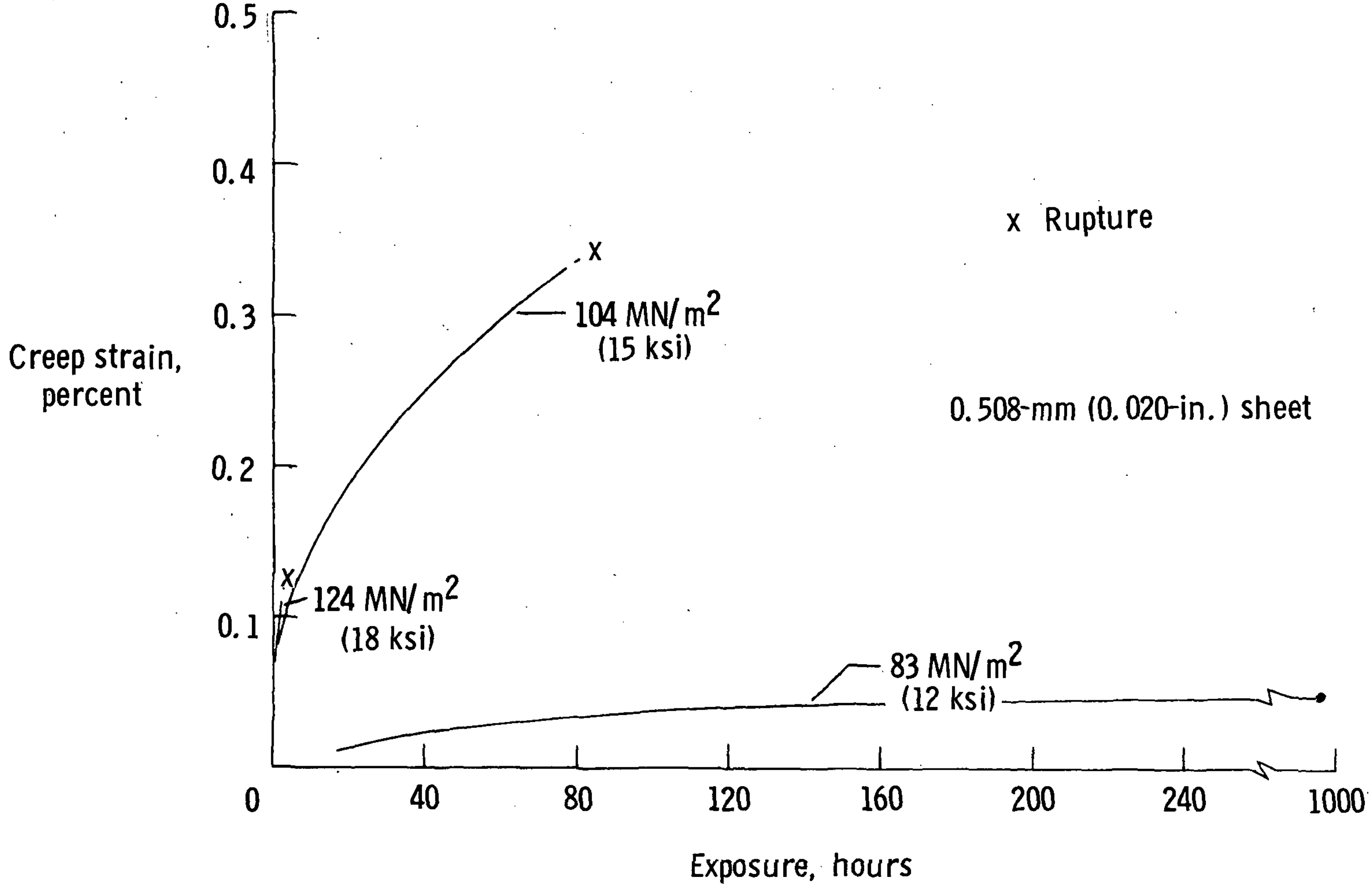

(b) 1256 K (1800° F) at 1.0664 kN/$m^2$ (8 torr).

Figure 12.- Continued.



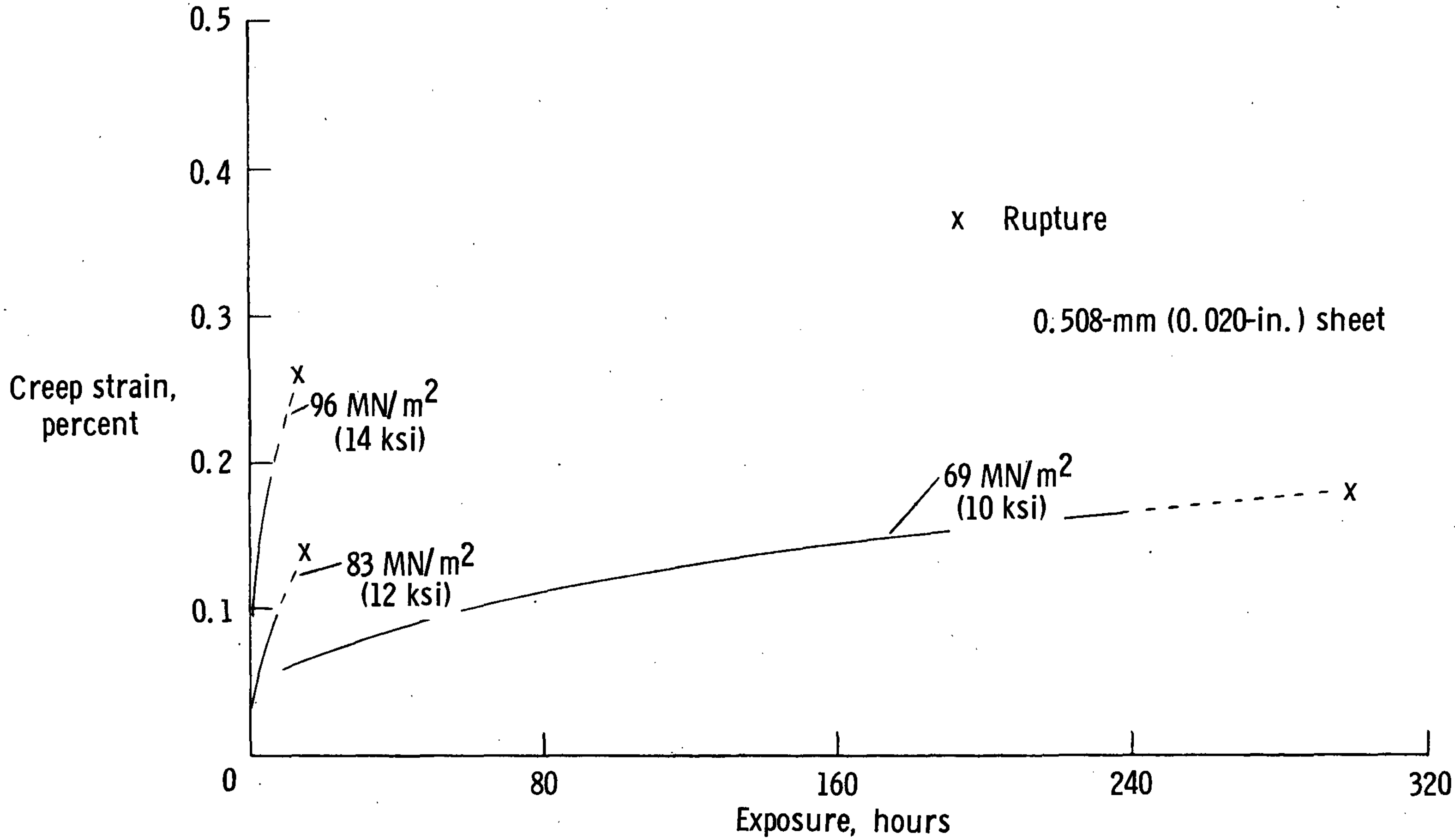

(b) Concluded.

Figure 12.- Continued.




(c) 1145 K (1600° F) at 0.1333 kN/$m^2$ (1 torr).

Figure 12.- Continued.




(d) 1256 K (1800° F) at 0.1333 kN/m$^2$ (1 torr).

Figure 12.- Concluded.

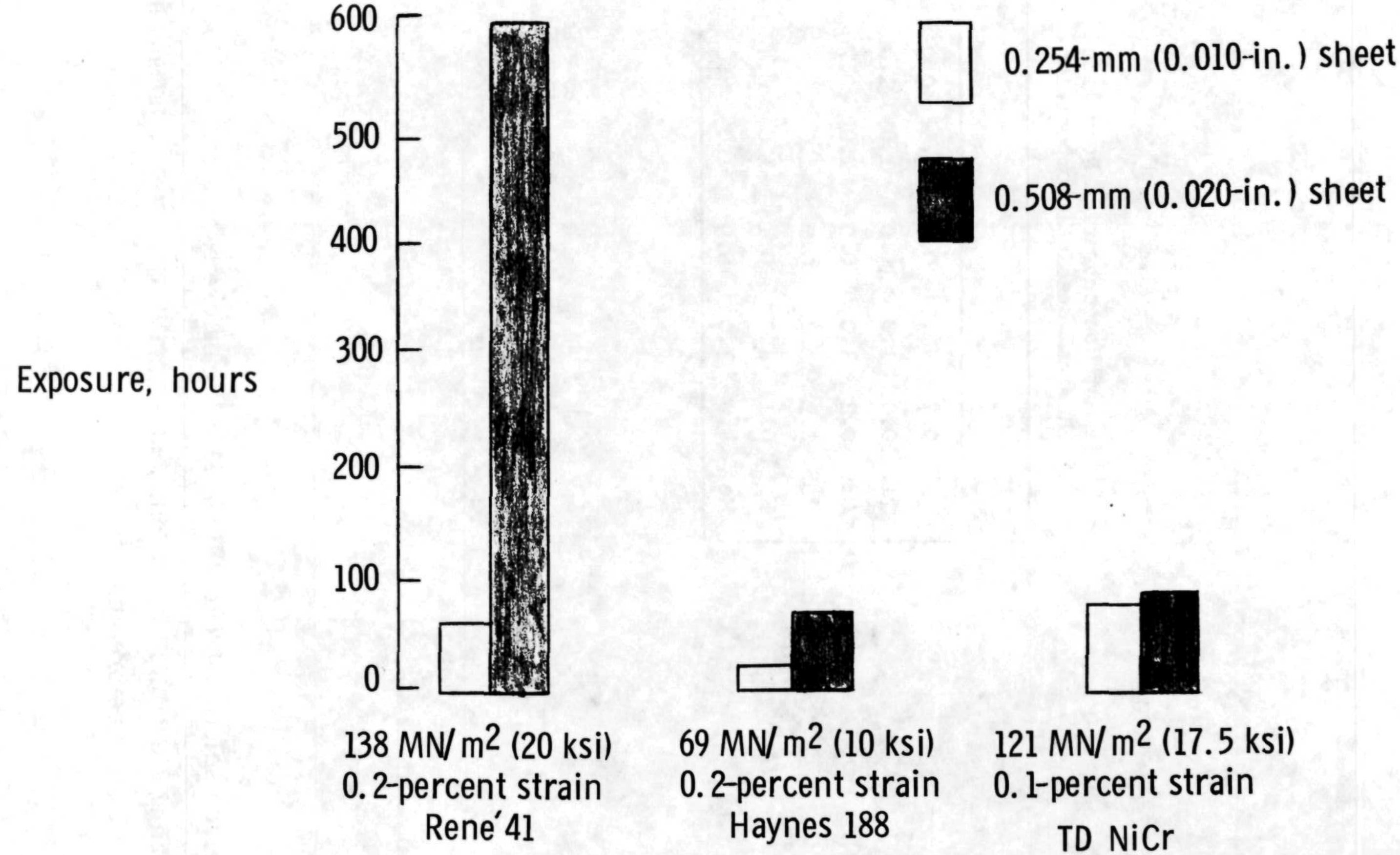
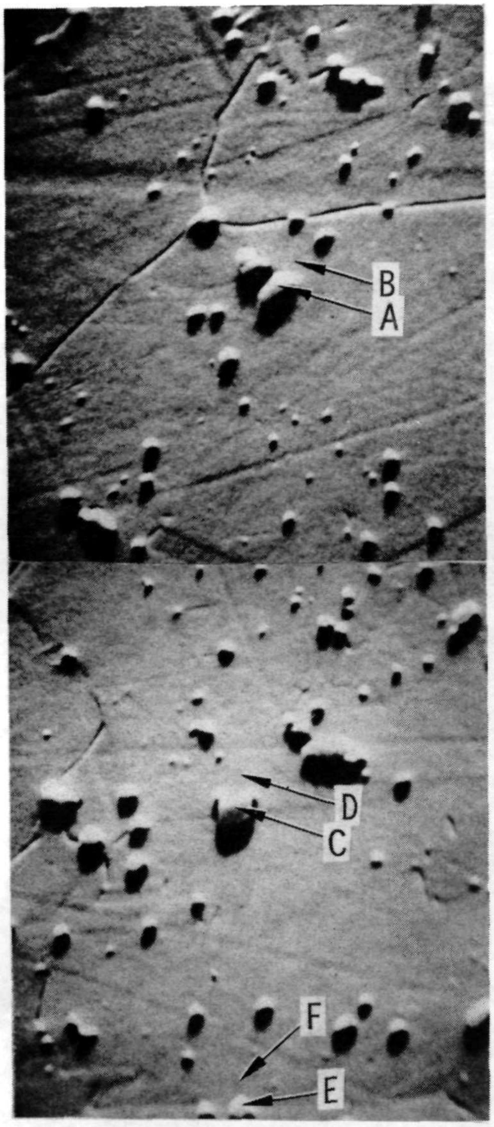



Figure 13.- Effect of sheet thickness on creep resistance of selected superalloys at 1033 K (1400° F).

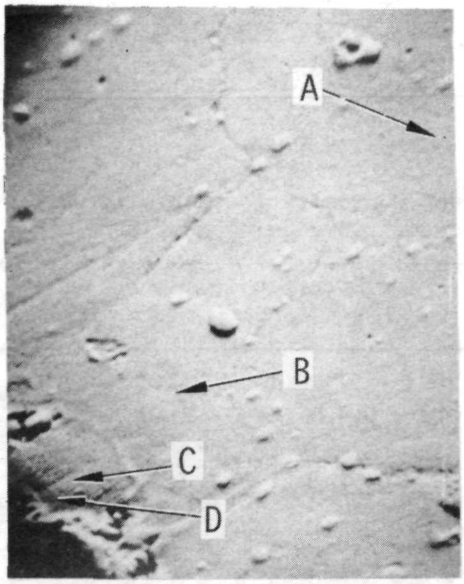



**Element Concentration Normalized To Nominal Chemical Composition**

| | Location | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| Al | 0.7 | 1.0 | 0.5 | 1.0 | 0.9 | 1.0 |
| Ti | 10.0 | 1.0 | 19.0 | 1.0 | 1.0 | 1.0 |
| Cr | 0.2 | 1.0 | 0.0 | 1.0 | 0.7 | 1.0 |
| Co | 0.1 | 1.0 | 0.0 | 1.0 | 0.6 | 1.0 |
| Ni | 0.1 | 1.0 | 0.1 | 1.0 | 0.4 | 1.0 |
| Mo | 4.0 | 1.0 | 0.9 | 1.0 | 5.0 | 1.0 |

(a) As-received solution-treated René 41 alloy before exposure. ×1740.

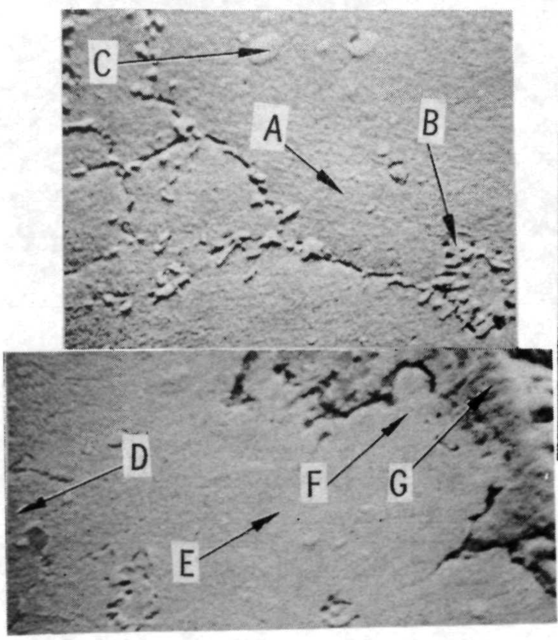
Figure 14.- Scanning electron micrographs and normalized element concentrations for René 41 alloy before and after exposure to the conditions noted.




**Element Concentration Normalized To Nominal Chemical Composition**

| | Location | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Al | 1.4 | 1.1 | 1.1 | 1.0 |
| Ti | 1.1 | 1.1 | 1.0 | 0.3 |
| Cr | 1.0 | 1.0 | 1.0 | 0.5 |
| Co | 1.0 | 1.0 | 0.9 | 1.0 |
| Ni | 1.0 | 1.0 | 1.0 | 1.0 |
| Mo | 1.2 | 0.9 | 1.1 | 1.0 |

(b) René 41 after 100 hours of exposure at 1033 K (1400° F). ×1740.

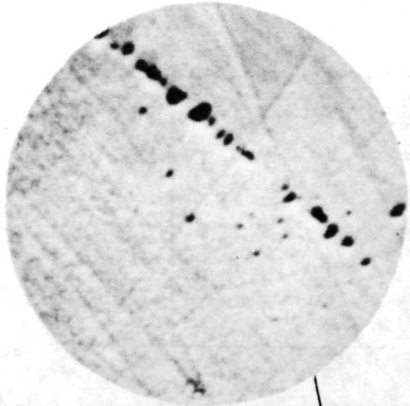


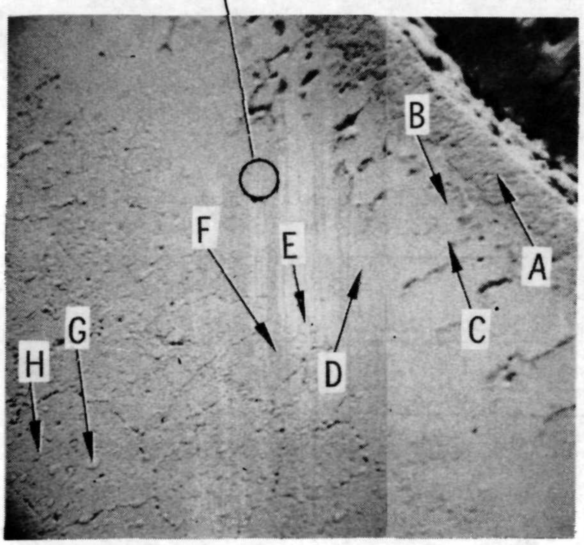

**Element Concentration Normalized To Nominal Chemical Composition**

| | Location | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| Al | 1.2 | 1.4 | 1.2 | 1.2 | 1.3 | 0.5 | 0.2 |
| Ti | 1.0 | 0.5 | 1.3 | 1.0 | 0.9 | 0.0 | 0.7 |
| Cr | 1.1 | 0.8 | 0.8 | 1.0 | 0.7 | 0.1 | 3.0 |
| Co | 1.1 | 0.9 | 0.6 | 1.0 | 1.1 | 1.3 | 0.0 |
| Ni | 1.0 | 0.5 | 0.4 | 1.0 | 1.1 | 1.2 | 0.0 |
| Mo | 1.0 | 4.0 | 6.0 | 0.9 | 1.1 | 2.0 | 0.0 |

(c) René 41 after 1000 hours of exposure at 1033 K (1400° F). ×1740.

Figure 14.- Continued.






Element Concentration Normalized
To Nominal Chemical Composition

| | Location | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H |
| Al | 0.5 | 0.5 | 0.6 | 0.4 | 1.2 | 1.0 | 1.1 | 1.0 |
| Ti | 1.0 | 0.6 | 0.0 | 0.4 | 0.9 | 1.0 | 1.4 | 0.9 |
| Cr | 3.0 | 0.4 | 0.3 | 0.7 | 1.0 | 1.0 | 0.8 | 1.0 |
| Co | 0.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 0.7 | 1.0 |
| Ni | 0.0 | 1.3 | 1.0 | 1.0 | 1.1 | 1.0 | 0.4 | 1.0 |
| Mo | 0.0 | 1.0 | 1.4 | 0.9 | 1.1 | 1.0 | 6.0 | 0.9 |

(d) René 41 after 100 hours of exposure at 1256 K (1800° F). ×435.

Figure 14.- Concluded.

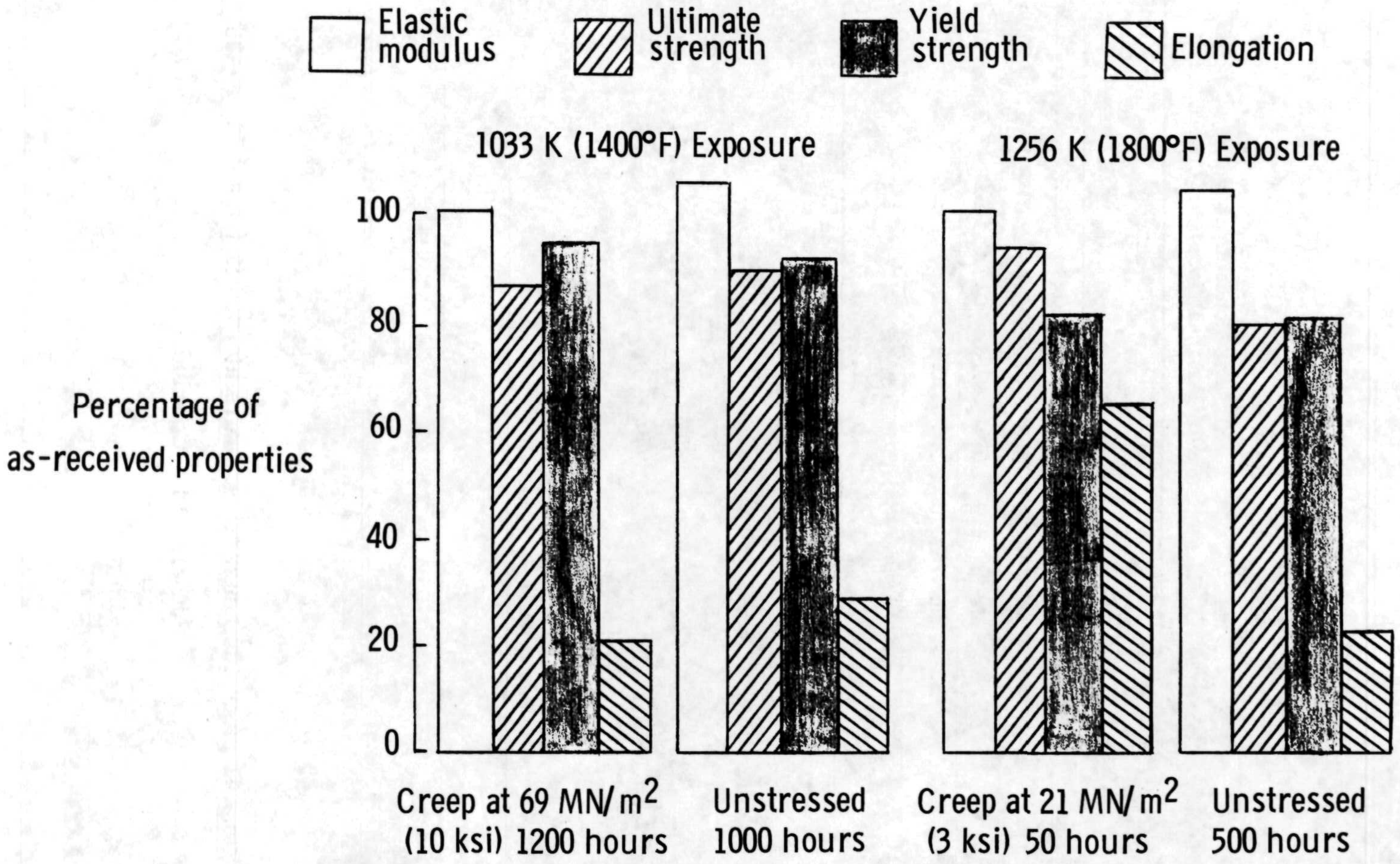
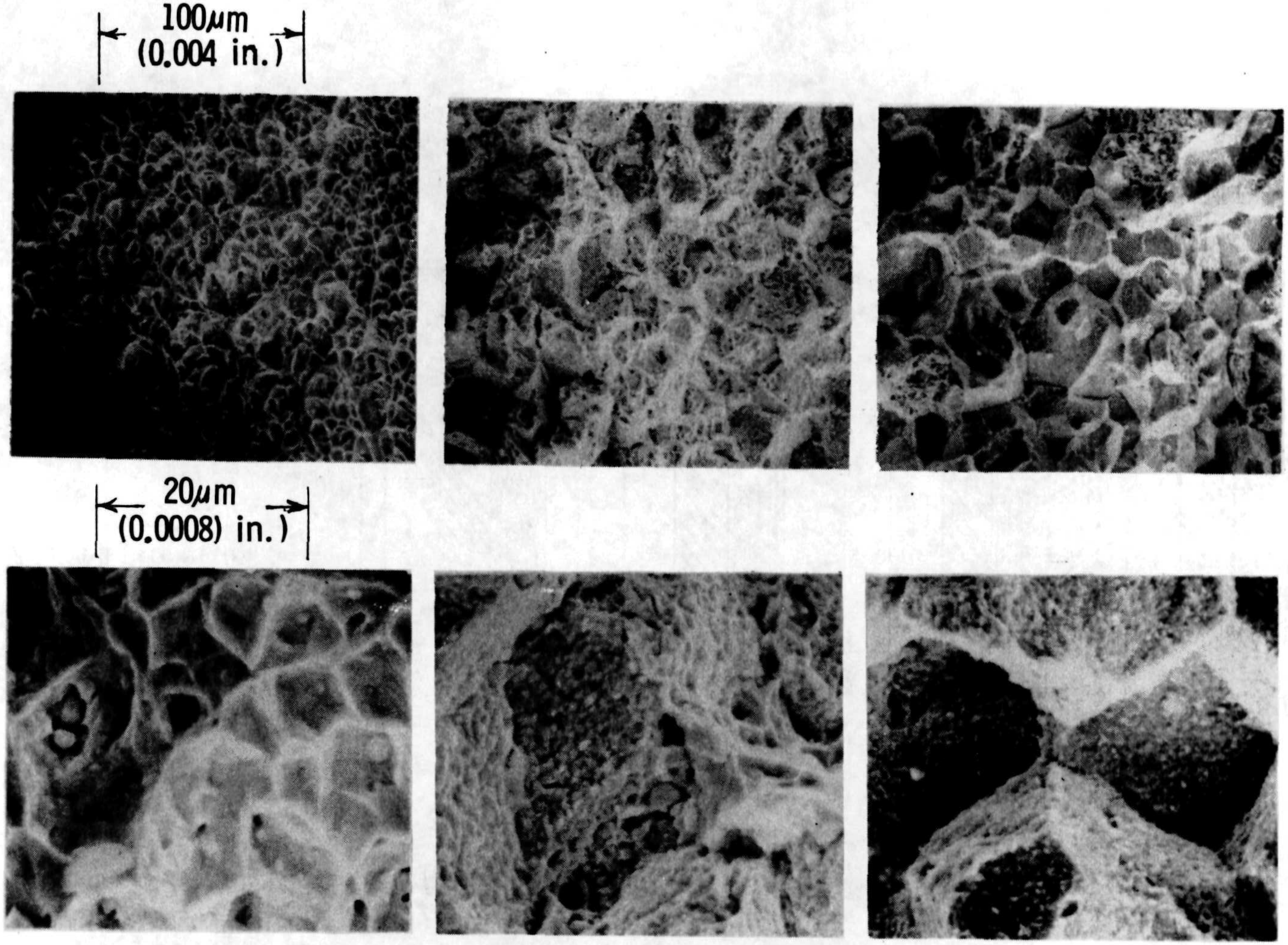



Figure 15.- Room-temperature residual tensile properties for Haynes 188, 0.508-mm (0.020-in.) sheet.




(a) Before exposure.

(b) After 20 hours, 34 $MN/m^2$ (5 ksi), 1256 K (1800° F).

(c) After 2000 hours, 52 $MN/m^2$ (7.5 ksi), 1033 K (1400° F).

Figure 16.- Scanning electron microscopy fractographs of Haynes 188, 0.508-mm (0.020-in.) sheet.

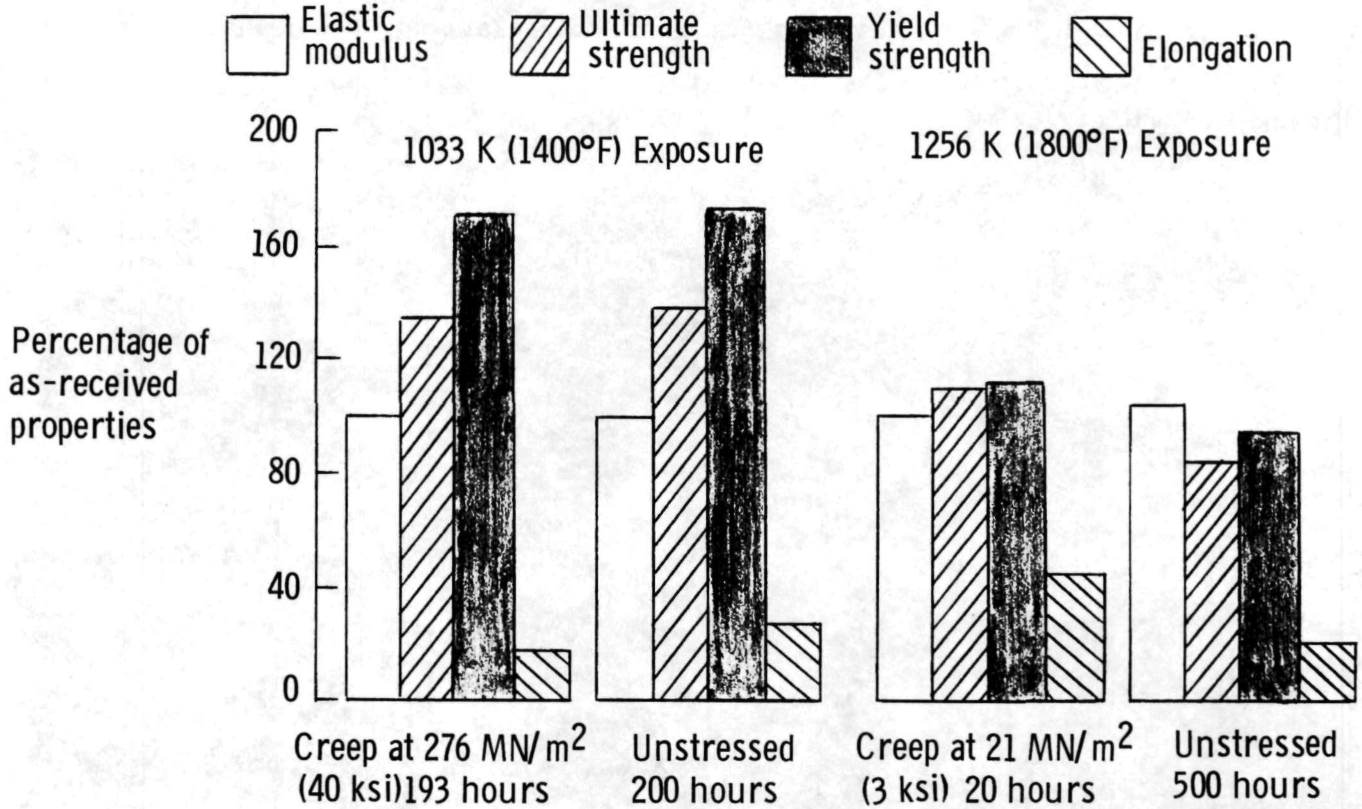
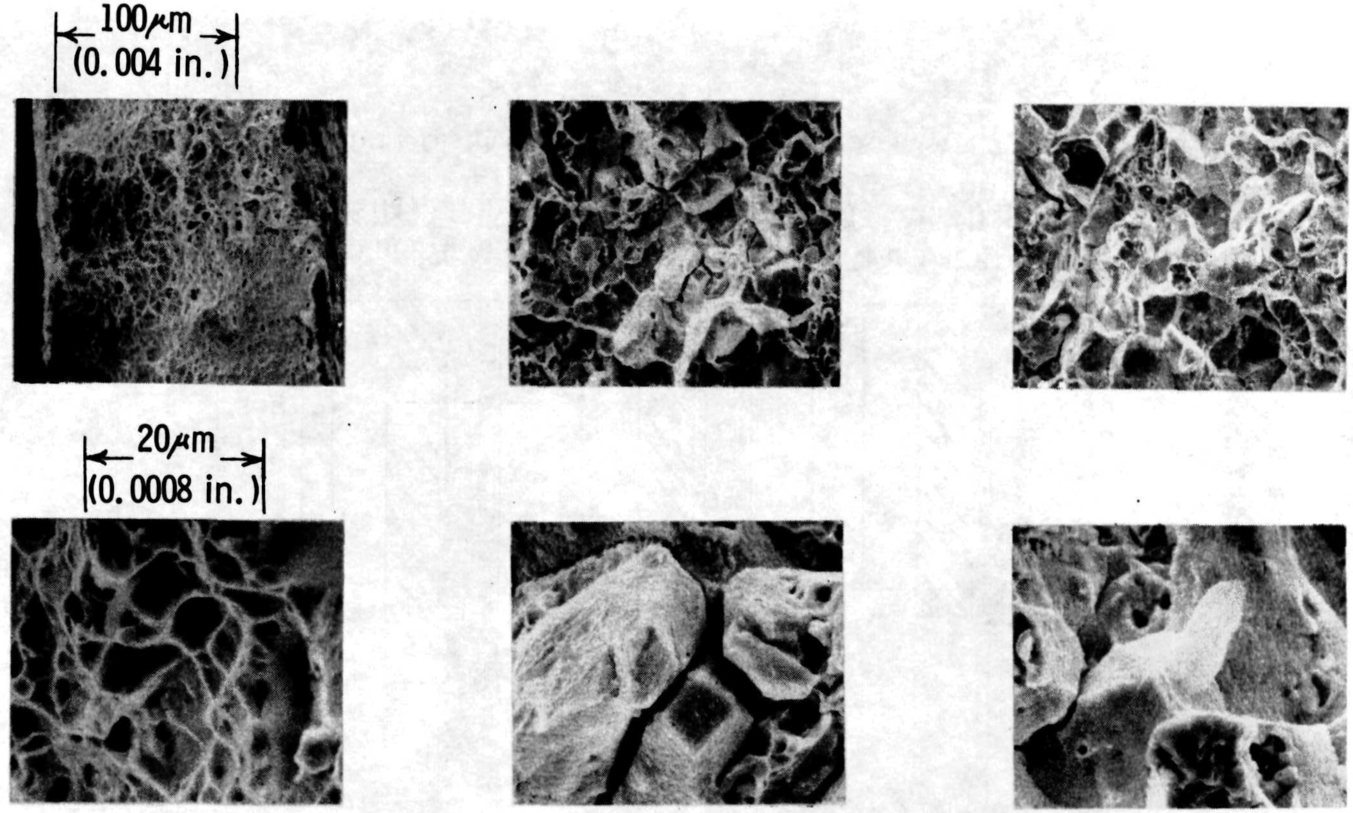



Figure 17.- Room-temperature residual tensile properties for René 41, 0.508-mm (0.020-in.) sheet.




(a) Before exposure.

(b) After 200 hours,
0 stress,
1033 K (1400° F).

(c) After 193 hours,
276 MN/m$^2$ (40 ksi),
1033 K (1400° F).

Figure 18.- Scanning electron microscopy fractographs of René 41, 0.508-mm (0.020-in.) sheet.

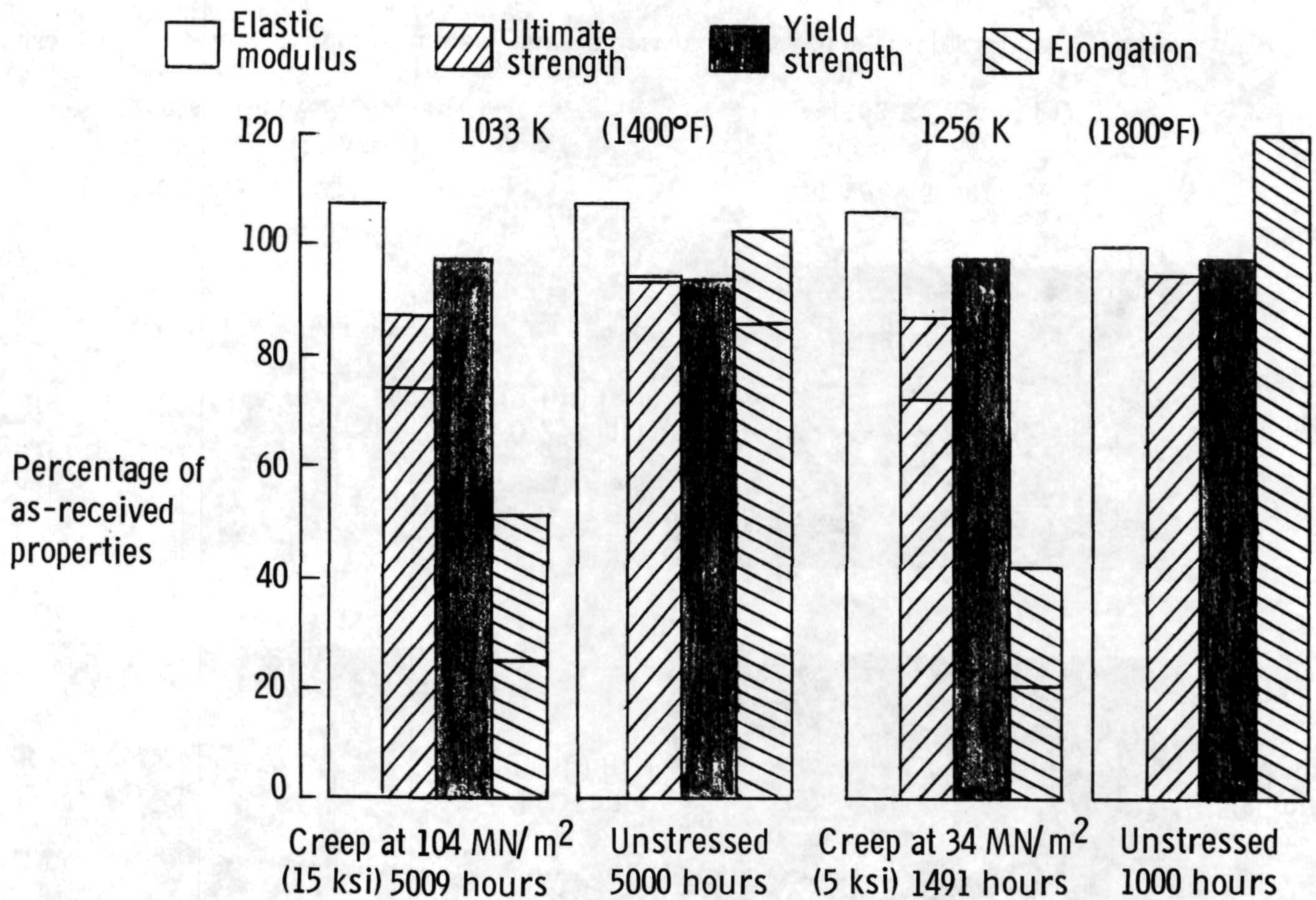
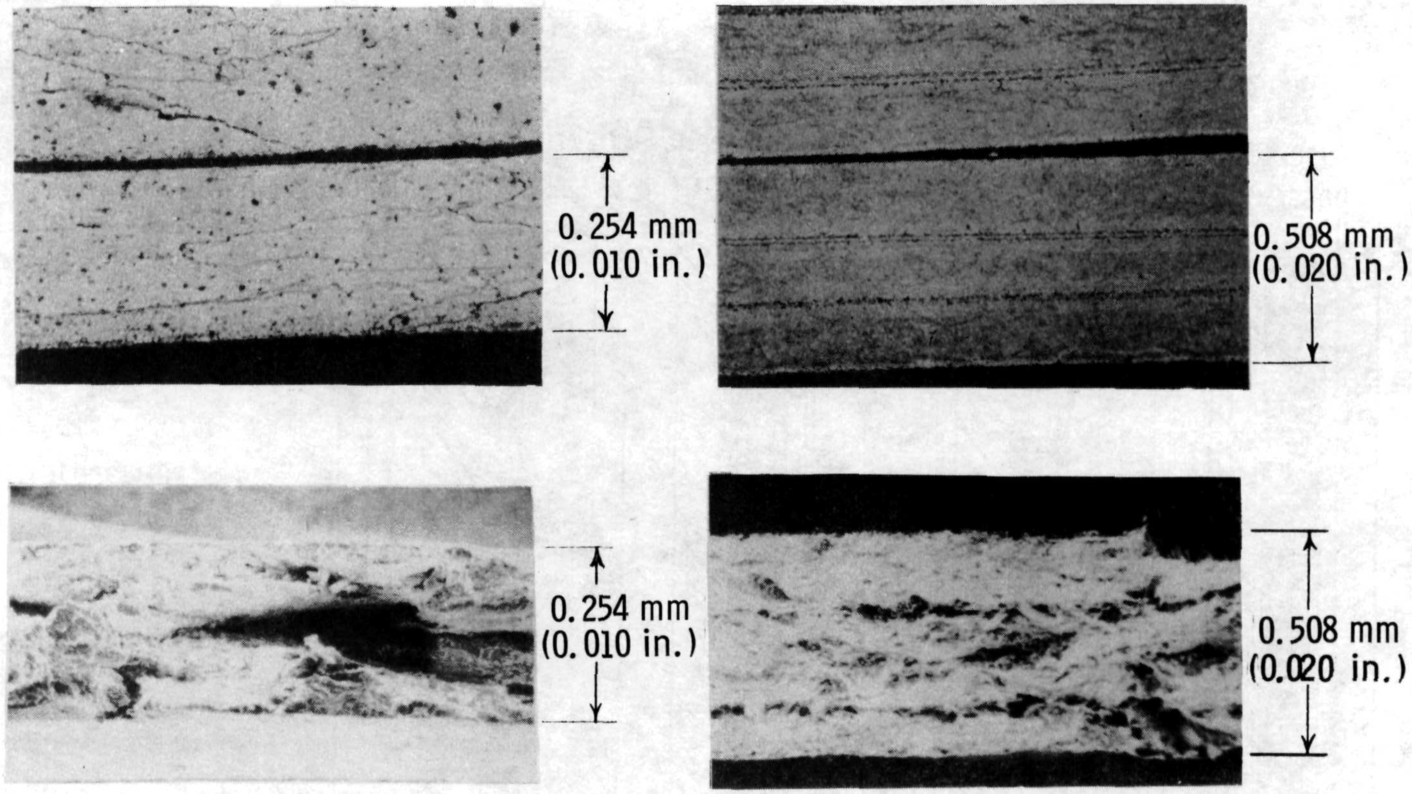



Figure 19.- Room-temperature residual tensile properties for TD NiCr, 0.508-mm (0.020-in.) sheet. (Horizontal bars represent individual data.)




(a) After 3.3 hours,
104 MN/m$^2$ (15 ksi),
1256 K (1400° F).

(b) After 5000 hours,
0 stress,
1033 K (1400° F).

Figure 20.- Microstructure and scanning electron microscopy fractographs of TD NiCr sheet.



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